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Practical Mental Hygiene in Industry

Accidents from the Point of View of the Workmen's Compensation Act, England

The Causation of Industrial Accidents

Atmospheric Particulate Matter: I. Dust, with a New Apparatus for Its Determination

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PRACTICAL MENTAL HYGIENE IN INDUSTRY*

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THE author is not a psychiatrist and this paper is merely an account of some of his experiences, as an industrial physician, in the wide field of mental hygiene.

Mental hygiene may be defined as that branch of medicine which has as its object the preservation of mental conditions which may endanger or are endangering either the mental or the physical health of individuals, or both.

Study of this definition reveals at once that mental hygiene is not a new subject to physicians. When a physician reassures a patient who is unduly alarmed about his physical condition, he practises mental hygiene. When he makes a thorough chest examination which appears needless to him, merely in order to convince a patient that his lungs are not tuberculous or his heart diseased, he again practises mental hygiene. Nevertheless, a study of the work which has already been done along this line by psychologists and psychiatrists will aid us in practising mental hygiene as a science rather than as a haphazard and intuitive procedure.

This study has been much delayed on the part of physicians for several reasons. Psychological quacks of all sorts have brought it into disrepute. Physicians have misused it. Freudian theories have been greatly misrepresented to us and are perhaps not entirely accurate for Freud is merely one of many authorities, even on the subject of psycho-analysis. Reputable authorities on the subject, when given opportunities to explain their work to us, have offered only generalities which meagerly instructed us. Yet the fault has been ours in part. We recognized and accepted gross insanity as well as hysteria, epilepsy, and kindred states. We accepted the work of physiologists such as Can-

*Read before the joint meetings of the Industrial Hygiene Section of the American Public Health Association and the Ohio Association of Industrial Physicians, Cleveland, Oct. 17, 1922. Received for publication Feb. 20, 1923.

non and Pawlow who demonstrated that digestion could be aided on the one hand, or made to cease entirely on the other, by the induction of different mental states. Yet we tended to scoff at psychotherapy instead of trying to learn how to use it to the best advantage. Can it be that the profession which is noted for its courage has been afraid of this subject?

Nevertheless, much is already being done in industry in the field of mental hygiene, largely under a protective coloring. This protective coloring will probably be necessary for some time in order to avoid the antagonism of employees. They may be proud of their physical ills; they are certainly seldom ashamed of them. Rarely, however, will they fail to resent the slightest implication that they are ill mentally; yet under mental hygiene may well be included all the service work done in industry. This work, like that of many physicians, is done without special training which would enable the workers to develop it to the highest possible degree of usefulness.

Another type of mental hygiene which is now quite common in industry is that having to do with environment. Clean, light, well-ventilated factories, recreation facilities, comfortable rest rooms, music, cafeterias, and factory newspapers: all these have their place in promoting the mental health of employees.

Mental hygiene in industry, as it falls within the special province of the physician, should begin with the hire of employees. There is, no doubt, much that the physician can do to prevent applicants from being accepted for work for which they are unfitted, because of nervous or mental conditions. I have not been able, however, to extend this work beyond the place which it has reached in usual practice. I do little more than try to exclude gross conditions such as epilepsy and actual insanity.

Medical Cases of Mental Origin

In order to make the medical cases which follow more comprehensible it seems necessary to discuss briefly the mental situation of the great mass of the industrial population. Too often one thinks of the factory worker as a stolid automaton, unemotionally working out his hours, trudging home to an equally colorless wife to sup on a smelly stew, spending the evening in sleepy, shoeless ease with occasional riotous celebration and with never anything approaching thought or emotion. You will agree with me, on the basis of your experience, that this conception is wrong. The emotional life of the factory employee is as varied and as complex as yours or mine; in fact, the part played by emotions varies inversely with the degree of intelligence. In direct relation to the degree of contentment, which in turn depends upon the mental adjustment to the problems of life, you have either smoothly running machines or revolt. In industry, as in any other large group of people, it will be found that these degrees of adjustment and their results shade into each other somewhat as follows: at the top, perfect adjustment, contentment, and efficiency; midway, restlessness and unhappiness; finally, complete failure in adjustment leading to disease and outwardly to revolt.

Everyone knows that the number in the first group is very small; the contented person is very rare. Obviously, then, since the duty of the physician in industry is the promotion of efficiency in the employee, it is properly a considerable part of that duty to remove the

mental causes of inefficiency. In order to do this, the environment should first be made as satisfactory as possible. Every effort should then be made to discover employees who are dissatisfied; to ascertain their problems; and to learn whether these problems are manifesting themselves in neuroses, obsessions, phobias, hysterical manifestations, or other mental or physical symptoms. Since these are the people who are always consulting physicians only to be told that there is nothing wrong with them, there will be little trouble in discovering them. After their condition is learned, the problem is to remedy it either by aiding them to compromise in hobbies or other satisfactory outlets for misdirected or lost energy, or by explaining it to them and encouraging them to face it courageously and strive to overcome it. The latter method may require some psycho-analysis.

Cases in Which a Compromise Was Effected

I have had a considerable number of cases in which I have been able to alleviate nervous conditions by having the patient compromise them in other outlets. In fact, it has become my custom not to wait for symptoms to appear before using this method. When it is found in the course of the annual physical examinations that the patient is of the nervous type and when questions reveal that he does nothing except work, eat, sleep, and worry, it is explained to him that he is leading a potentially unhealthy life. Having nothing interesting to divert his mind, he works, from a mental viewpoint, at one thing for twenty-four hours a day. He is advised of the value of a hobby and definite suggestions are made as to the type most likely to interest a man of his personality. If no symptoms are yet present it is not possible to judge of the value of the results. Fortunately, I have had a number of cases in which symptoms had already developed and in which this method of treatment was successfully used. As all of these cases are much alike, I will relate but one.

Case 1.—R. B., white, male, married, an executive, aged 35, suffered for several weeks during the late winter and early spring from a mild rhinitis which seemed to bother him out of proportion to its severity. He developed insomnia. Physical examination was negative except for a hemoglobin of 75 per cent. Medication failed to bring improvement in his condition. Questions revealed that he had no active interest in anything outside his work and his family, and that he almost always spent his evenings in purposeless reading. He was strongly advised to find a hobby. In the course of the discussion he showed considerable interest in gardening and he was therefore told to begin making a garden at once. He followed this advice and immediate improvement resulted. The rhinitis disappeared; his hemoglobin returned to normal within a few weeks; and he became far more cheerful and pleasant in his dealings in the plant. The improvement was so apparent to the patient himself that he stated that he was certain that, had it occurred a few years sooner, he would now be much further advanced in his position. He realized that he had been greatly handicapped in his work for many years.

The physical exercise of gardening may have contributed to the improvement in this instance. Even if it was entirely responsible—a possibility which I cannot accept on account of the mental change which the patient showed—this does not in the least detract from the value of the method by which the improvement was obtained. Indeed, a hobby which combines physical exercise with mental diversion is to be recommended. Mental and physical hygiene should go hand in hand.

What happens in this type of case?

What is the mechanism of this compromising of conflicts, as the psychologists call it? To me it is easy to understand when I compare it with physical hygiene. By exercise we strengthen the body and increase its resistance against infection. The pursuit of a hobby or other mental diversion is mental exercise which increases the resistance of the mind and enables it to carry a heavier load without becoming diseased. This method of treatment is easily employed and there is no danger that its use will cause unpleasant misunderstandings on the part of the patient.

Cases Psycho-Analyzed

I have had several cases in which the second method, which includes psycho-analysis, was successfully used. The following are cited as illustrations:

Case 2.—R. L., white, female, aged 28, and unmarried, complained of very severe pain with the distribution usual to renal colic. She gave a history of nausea and vomiting, and of frequent urination, but there was no hematuria. Her temperature was normal; her pulse rate, slightly above normal. She obtained no relief from the injection of 1/4 grain of morphine and 1/100 grain of atropine which was repeated in less than an hour; she did not believe that this medicine would help her. She said during the attack that her mother had had similar attacks which had been cured by a chiropractor, and she asked that one be called. She showed how the chiropractor had made thrusts in the flank, and, with some sense of humor, I imitated these quite forcibly, to her great relief. The pains subsided rapidly afterwards, and only a slight soreness was present on the following day. X-ray examination gave negative results. No stone was passed.

Questions revealed that this patient had assisted in caring for one of the officials of the company who had had an attack of real renal colic a few weeks previously. Her case was diagnosed as hysteria and the condition was explained to her. She was referred for psycho-analysis which she did not complete. She went far enough, however, to accept the belief that her pain had been entirely mental in origin, and she has not had the slightest symptom of recurrence in the six months which have since elapsed.

The diagnosis of hysteria was based on the negative X-ray findings, on the almost normal pulse and lack of hematuria, on the patient's mental attitude, on the failure of the morphine and atropine which she knew would not help her, and on the immediate cessation of symptoms after I went through the mummery of the chiropractic "thrust." The fact that she had recently attended a patient with renal colic was also suggestive. It should be noted that she had all the symptoms which she, as a laywoman, had seen, and none which she had not seen.

Case 3.—A. H., white, female, aged 38, unmarried, a lamp baser, was sent to the dispensary by her foreman with the complaint that after four years of good service her work had gradually become so poor that she was no longer a profitable employee. The service secretary gave the information that the patient had recently lost a niece to whom she had been devoted and that she was grieving over her death. The patient was found to be in a state of melancholia approaching insanity of the manic-depressive type. She suffered from weakness and insomnia. When she slept, she dreamed of her niece and arose in her sleep to go to her; that is, she had some degree of somnambulism. She wanted to die and join her niece in heaven. Indeed, she admitted having contemplated suicide and was deterred by her religion alone, in which, however, she was beginning to lose faith. She had unreasonable phobias for crowds and interiors of large buildings. She was poorly nourished. Anorexia was so marked that she was eating but very little, far less than enough to maintain proper nourishment. Marked anemia was present.

Psycho-analysis was begun by the author and was carried on later by an outside analyst. Rapid improvement in the patient's condition was noticed. Three weeks after analysis her foreman reported that her work was again satisfactory. After fourteen sessions at weekly intervals the patient suddenly realized that she had been acting in a childish way and

announced that thereafter she would stand on her own feet. Psycho-analysis was therefore discontinued. The patient went out of her way to do things of which she was formerly very much afraid. She started attending social functions and amusement parks with other factory girls, and displayed an awakened interest in her personal appearance. In brief, she became a normal woman.

It would be impossible even to indicate here the steps in the psycho-analysis of this case but I have tried to relate enough to show the value of the procedure. These short analyses are not complete; indeed, it is hardly the function of the physician in industry to do anything so time-consuming as to make complete psycho-analyses. They are, however, sufficient to secure a return to a state of efficiency comparable to that of other employees.

Mental Hygiene in Accidents

Even in connection with accident surgery, there is a wide field for mental hygiene. As Stevens says, the length of disability after an accident depends far more on what the patient thinks about his injury than on the actual resultant physical condition. Mental states, such as anger and fright, may enter as factors in increasing the length of disability. Actual malingering in the sense in which this word is ordinarily understood is extremely rare, and when a case exhibits evidence from which the physician is led to suspect it, it should be remembered that the patient is probably deceiving himself more than anyone else and his reason for doing this should be sought and set before him—or better, he should be so handled at the time of injury that malingering will not occur. A considerable part of the compensation paid for accidents could be saved by proper handling of such cases.

The following case exemplifies some of these points:

Case 4.—E. D., white, male, aged 43, married, an electrician, injured his right arm in the region of the external condyle by bumping it against a wall. When his arm was examined the next day there was merely a slight swelling. He claimed, however, that he had not slept the previous night on account of pain. The arm was soaked in hot water and bandaged in order to limit the motion. The patient was not seen for two weeks, at the end of which time he came in, in a belligerent mood, and reported that his arm was no better. When asked why he had not come sooner, he said angrily that he thought I considered the accident too trivial to bother with. On being scolded for taking such an attitude he admitted that he had been wrong. Coal-tar drugs, hot soaks, and bandaging failed to relieve the pain. He refused to stay at home. Every effort was made over a period of three weeks to assure him that the injury was not serious. These efforts included consultations with a surgeon and a neurologist, both of whom assured him, without result, that there was no evidence of injury. As he had the fixed idea that the external condyle was a lump due to the injury, I measured both his arms at this point with calipers in order to demonstrate that there was no difference between the well arm and the one which had been injured. Pain began to diminish after this but recovery was slow.

This man should have been sent for and made to report at the dispensary the day following the accident. Such a procedure would probably have averted much of his pain. It will be noted that this patient nursed his anger against the physician for a considerable length of time because he thought that he had made light of a serious condition.

In contrast with the foregoing is the following case:

Case 5.—L. Z., white, female, aged 20, unmarried, received a back injury when a girl pulled the chair from behind her as she was about to sit down at her machine. She was angry at the girl when she came to the dispensary. As I had learned from past experience, such as that in Case 4, what effect anger might have upon the length of disability, I gave the girl a careful physical examination

and then, although I found no serious injury, sent her in the company car for an X-ray examination which was also negative. Thence she was taken home in the company car. The car was also sent the following day to bring her to the dispensary, where the results of the X-ray examinations were explained to her, and she was informed that the girl who had been responsible for her injury had been strongly reprimanded. She was ordered to rest another day after which, she was told, her injury would be entirely healed. She left quite satisfied and returned to work on the day set by the physician, and has had no trouble since that time.

In this case it will be seen that care was taken so that the patient would have no reason to believe that I thought her injury of little moment. It should be noted also that, since the other girl had been reprimanded, her desire for revenge was satisfied and there was no further cause for her anger to persist. It is admitted that she might have recovered as rapidly without these precautions, but back injuries in industrial work may be so serious from the legal point of view that I feel that the utmost care is justified in every case.

It is of supreme importance in every accident to learn whether the patient is angry at some one whom he blames for being the cause of his injury. If he is it is equally important to discover some means for immediately satisfying the desire for revenge which often results from such a mental condition. Otherwise the patient is very likely to develop a mental state in which he obtains his revenge by prolonging the disability, with the idea of making the other person sorry.

Difficulties Encountered in Practising Mental Hygiene

It is inevitable that difficulties should arise as soon as an effort is made to introduce a new idea, and in my experience this has been true in connection with mental hygiene. Freudian or even near-Freudian views in connection with analysis are, I believe, almost certain to cause trouble, and have to be advanced with great caution; if used at all with patients of the opposite sex, they should be employed in selected cases only. Great care is likewise necessary in order to prevent patients from feeling that the physician implies a mental inferiority in suggesting mental treatment. In my experience the method of compromising mental conflicts in hobbies, etc., is the most easily used, requires the least time, and has never caused any difficulties. In mild conditions, it is sufficient in itself to cure numerous cases of what is commonly called "nervousness."

The results which I have obtained have made it well worth while to struggle with the difficulties. In addition I have been stimulated by a strong belief that the physician who fails to practise mental hygiene fails to live up to the highest ideals of his profession. In days past the family doctor knew all the joys and sorrows of his patients. He was counselor and friend as well as physician; in fact, we see now that he practised mental hygiene although he never heard the term. As this type of practitioner disappears we see the mushroom growth of a host of quacks—quack psychologists, religious healers, quack rubbers, quack thrusters, and quacks of numerous other sorts. The patients who can be cured by such means are cured by mental suggestion, and when the medical profession generally has learned to practise scientific mental hygiene all of these quacks will be at an enormous disadvantage. It is doubtful whether any other one step could do more to put them out of business. This fact in itself should

be sufficient spur to lead physicians to make the effort required to gain an understanding of this subject.

Conclusions

The success of every physician, and especially of every physician in industry, has always depended largely on his practice of mental hygiene.

With the development of mental hygiene as a true science every physician owes it to himself and to his patients to learn to practise it scientifically. Failure to do so will put this part of the physician's work in the same class as that of quacks.

The practice of mental hygiene will do more to eradicate quackery than will any other single course of action.

ACCIDENTS FROM THE POINT OF VIEW OF THE WORKMEN'S COMPENSATION ACT, ENGLAND

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What Is an Accident?

THERE is in the English language no one short definition which will cover all the different interpretations which may be placed on the word "accident."

Definition.—Derived from the latin *accidens*, a falling upon, it denotes a chance event and is generally used of an unlucky, but sometimes of a lucky event. Besides its ordinary meaning of chance, it may in grammar signify a variation, or, in logic, one of the five predicables (genus, difference, species, property, accident). In Locke on the Human Understanding (1689) and in Berkeley's Principles of Human Knowledge it is used as a synonym of quality.

In law—by law is meant a rule or command prescribed and imposed by authority—the word connotes an event happening without the concurrence by the will of the person by whose agency it was caused.

In equity—by equity is meant a fair adjustment of conflicting interests—it connotes an event which is not the result of personal negligence or misconduct. Law and equity are not always identical, as is shown by the practical working of the Workmen's Compensation Act.

House of Lords Definition.—Lord Macnaughten in the case of Fenton v. Thorley defined an accident as "an unlooked for mishap or an untoward event which is not expected or designed." All the Law Lords present concurred and in a later case the Lord Chancellor adopted this definition.

The English Factory and Workshops Act combines and includes under one head "Accident or Dangerous Occurrence." The Workmen's Compensation Act, 1906, makes the term "Accident" include several diseases; thus Section 8 states that where "the workman is suffering from the following diseases and is thereby disabled from earning full wages . . . and the disease is due to the nature of any employment in which the workman was employed at any time within the twelve months previous to the date of the disablement . . . he shall be entitled to compensation as if the disease were a personal injury by accident":

Schedule of Industrial Diseases

1. Arsenic poisoning or its sequelae.
2. Lead poisoning or its sequelae.
3. (*a*) Poisoning by benzene and its homologues, or the sequelae.

(*b*) Poisoning by nitro and amido derivatives of benzene and its homologues (trinitrotoluene, aniline, and others), or the sequelae.

4. Poisoning by dinitrophenol or its sequelae.
5. Poisoning by nitrous fumes or its sequelae.
6. Dope poisoning; that is, poisoning by any substance used as or in conjunction with a solvent for acetate of cellulose, or its sequelae.

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7. Poisoning by tetrachlorethane or its sequelae.
8. Poisoning by carbon bisulphide or its sequelae.
9. Poisoning by nickel carbonyl or its sequelae.
10. Poisoning by Gonioma Kamassi (African boxwood) or its sequelae.
11. (*a*) Dermatitis produced by dust or liquids.

(*b*) Ulceration of the skin produced by dusts or liquids.

(*c*) Ulceration of the mucous membrane of the nose or mouth produced by dust.

(Not entitled to compensation if only disabled for employment in the particular process in which the disease has been contracted.)

12. (*a*) Epitheliomatous cancer or ulceration of the skin due to tar, pitch, bitumen, mineral oil or paraffin, or any compound, product or residue of any of these substances.

(*b*) Ulceration of the corneal surface of the eye, due to tar, pitch, bitumen, mineral oil or paraffin, or any compound, product or residue of these substances.

13. Chrome ulceration or its sequelae.
14. Scrotal epithelioma (chimney-sweeps' cancer).
15. Compressed air illness or its sequelae.
16. Cataract in glassworkers. (Entitled to only six months' compensation and to only four months' if not operated on.)
17. The disease known as miners' nystagmus, whether occurring in miners or others, and whether or not the symptom of oscillation of the eyeballs is present.
18. Subcutaneous cellulitis of the hand (beat hand).
19. Subcutaneous cellulitis over the patella (miners' beat knee).
20. Acute bursitis over the elbow (miners' beat elbow).
21. Inflammation of the synovial lining of the wrist joint and tendon sheaths.
22. Glanders.
23. Telegraphists' cramp.
24. Writers' cramp. (Compensation for not more than twelve months.)

Many of these industrial diseases have been added since 1906 by order of the Secretary of State in pursuance of the power conferred on him by Section 8, Subsection 6 of the Workmen's Compensation Act.

Proof of an Accident

If it is hard to define an accident, it is often as hard to prove and still more difficult to disprove in court the fact that an accident has occurred.

The four questions of importance to settle in a compensation case are: (1) Did an accident occur? (2) What are the injuries? (3) To what extent are the injuries (*a*) attributable to the accident? (*b*) aggravated by the accident? (4) What are the extent and duration of incapacity?

In a case not represented by counsel I once requested that my evidence should be taken first in order to save the time of the court. The judge, thinking that I was anxious only to save my own time, adopted the usual custom in England and heard the medical evidence last. After dragging wearily through much useless and contradictory evidence I was called and was able to prove conclusively (1) that there had been no accident, and (2) that the deceased had died a natural death.

In cases of alleged accident where no one witnessed the occurrence, and the *bona fides* of the claimant is more than suspect, much difficulty is presented in deciding the case in accordance with law and equity.

Accident Reports.—A surgeon should, at the earliest possible moment, make a complete report with respect to any accident with which he is concerned. Such action is needed in order (1) to avoid omission of essential details, and (2) to secure accuracy. Each report should be full and uniform.

The question arises as to the best form of report. I have recently written about a thousand letters to different firms asking for their coöperation in compiling forms for medical reports of

health examinations of workers. Among the replies are several forms which display much diversity of detail, whereas uniformity should be aimed at, as far as possible.

In England the Factory and Workshops Act, 1901, Ch. 22, Part 1 (iii), Section 19 (1) ordains:

> Where there occurs in a Factory or Workshop an accident which either: (*a*) causes loss of life to a person employed in the factory or workshop; or (*b*) causes to a person employed in the factory or workshop such bodily injury as to prevent him on any of the three working days next after the occurrence of the accident from being employed for five hours on his ordinary work, *written notice* shall forthwith be sent to the inspector for the district.

This written notice has to be filled out on Form 43 (*a*) if the person is killed, or (*b*) if he is disabled for seven days, and (*c*) under several other specified conditions. The details set out on the form are, in the case of an English factory, essential, and in any case, advisable. I suggest that the first part of an accident report should be an exact copy of the twelve items included on this form, which are as follows:

1. Name of occupier.....
2. Address of works.....
3. Nature of industry.....
4. Branch or department in which the accident occurred .....
5. Injured person's surname.....
   Christian names .....
   Address .....
6. (*a*) Sex....(*b*) Age (last birthday)....
   (*c*) Occupation .....
7. Date and hour of accident.....
8. Hour at which he started work on day of accident .....
9. (*a*) Cause of accident .....
   If caused by machinery:
   (*b*) Give name of the machine and part causing accident .....
   (*c*) State whether it was moved by mechanical power at the time .....
   (*d*) State exactly what injured person was doing at the time .....
10. Describe briefly nature and extent of injuries (*e.g.*, fatal, loss of finger, fracture of leg, scald) .....
11. If the accident was not fatal, state whether injured person was disabled for at least one whole day .....
12. Has the accident been entered in the General Register? .....
    Signature .....
    Date .....

This form should be used for all accidents where English law obtains, except those of a purely trivial and temporary nature. The information may be filled in by a clerk, manager or agent, or whoever is responsible. The time of the physician will thus be saved, and he can devote himself to that part of the report which more especially concerns him. This second part of the report may, for the sake of economy, be printed on the back of the items already set forth.

Medical Officer's Report on Workman Accidentally Injured

Wages number and any other number, such as co-partnership.

A. This report is drawn up in view of possible litigation and for the purposes of the employer's solicitor. (The accident report should commence with this clause, whereas the health report should commence with *Strictly Private and Confidential.* This first clause enables the report to be presented in court.)

1. History of accident. Statement of injured worker, and, when convenient, to have this signed by him or by a witness. It should commence "He states" and, if not signed, should be enclosed in inverted commas. It should also give any details of importance occurring prior to the accident, and details of events after the accident—*e.g.*, Did the man get up unaided? Where did he go? How did he get there? Did he walk? Was he unconscious? When did he see a physician?

2. Was the man in good health at the time of the accident? If not, what was the nature of his ailment? (In addition to general health other points are often useful. After appar-

ently recovering from a trivial accident, a man once claimed compensation on the ground that he was ruptured. In my notes, made at the time of the accident, was one to the effect that he was wearing a double truss. Hence his claim was disallowed.)

3. Has he sustained any further injury? (I attach much importance to this question. It is, of course, possible that subsequent lesions may be discovered which were not apparent immediately after the accident, but it more frequently happens that the person claims compensation for a disability quite unconnected with the accident.)

B. Present Condition.

4. What is the exact nature and extent of the injury and its cause? (Make a note of the state of the patient's clothes; whether he is definitely under the influence of alcohol; his general appearance; his position; his gait; the way in which he removes his clothes; all physical or objective signs and subjective symptoms; the exact condition of the injured part; the presence of a wound, fracture or other lesion; redness, heat, swelling, deformity, altered sensation, the condition of the reflexes, etc.)

5. Extent of present incapacity. (This should also be given in percentage and repeated in figures — *e.g.*, twenty per cent. (20%). It is sometimes advisable to write "less than 20%" or "at least 20%." Much care is required and each case must be decided on its merits. During the late war a scale was drawn up by Parliament in 1914. This was amended by a select committee, adopted in a Royal Warrant May 21, 1915, and modified later. These figures are somewhat arbitrary and often unjust. For example, a man joined the army with defective vision in one eye. Although the disability was not sufficient to debar him from the army the difference between the two eyes was such that he practically used only one eye. During military service he lost the defective eye, and in accordance with the terms of the Royal Warrant he received a permanent pension of 50 per cent., although his disability was hardly increased. In contrast, two others—the one a clerk, the other a professional violinist—suffered amputation through the right elbow joint. They received only 60 per cent., although they were absolutely unable to follow their previous employment.)

6. Whether incapacity is likely to be temporary or permanent.

7. Probable duration of total or partial incapacity.

8. Question of complete recovery.

The prognosis, after an accidental injury, as to the extent and duration of the resultant incapacity is neither simple nor certain. On the one hand, a seemingly trivial accident may produce permanent incapacity of a serious nature. By far the commonest source of this incapacity is septic inflammation, frequently caused by carelessness.

On the other hand, many patients whose conditions are apparently incurable completely recover. During the late war while in charge of a surgical department in a military hospital, and after the war, as the representative of the Ministry of Pensions on a Dispersal Board in London, I saw many patients who had been placed in a low category or marked P. U. (permanently unfit) or awarded substantial pensions, but who are now free from any disability. Movements, massage, ionization and electricity aid modern orthopedic surgery to effect many miraculous cures. One such patient, whose disability was an injury to the thigh, is now captain of an important football team in London.

Some lesions may involve heavy legal liability although they may not be the actual cause of the incapacity. For example, a simple trephining of the skull after an accident does not necessarily cause the slightest disability, but if it is followed by epilepsy or any signs or symptoms of brain lesions, the accident would rightly be held to be responsible, and substantial compensation would be awarded in any court. Even a well-healed, healthy, superficial scar of the scalp is sometimes the only serious evidence in a successful claim in court. I am presuming that in this case the epi-

lepsy was neither caused nor aggravated by the accident.

The point which I wish to emphasize is that all subsequent signs and symptoms may be attributed to the accident unless proof is produced to negative such a proposition. The onus of such proof rests with the defendant in an action brought by the injured person against the employer. Employers will therefore be well advised in cases of this character, in which they admit liability to satisfy the claim of the plaintiff legally and promptly in final settlement.

Scene of Accident

If the physician arrives at the scene of the accident, after he has attended to the injured person he can be of the greatest use in making actual notes, on the spot, of the existing condition. Frequently there is most conflicting evidence as to the time and site. As he reaches the scene of the accident he should record the time. This will help to verify the data later.

He must also note the exact position of the injured person in relation to stationary objects. I remember an instance in which a man was killed by a motor lorry. Careful measurements were taken as to the position of the corpse in relation to the lorry. Later it became necessary in court to establish the exact site of the accident, as to which there was much conflict of evidence. The laborious record of detailed measurements was useless as the distance to some stationary objects had not been taken. In making these notes it is useful to have an assistant who can verify their accuracy if it is necessary to do so. A diagram with exact measurements taken at the time of the accident and verified by witnesses increases the accuracy and completeness of the report. Where possible I procure a photograph of the site of the accident.

It may be said that it is no part of the physician's duty to work up the case from a legal point of view. It is probable that, among all the people present on the site of an accident soon after its occurrence, the physician is the most capable to procure accurate information. Often he is the only person who can obtain evidence of a most vital character. As a citizen and a physician he should do his best in the interest of truth and justice.

Much valuable evidence, which is easy of proof at the time of the accident, quickly becomes obliterated. A recent case to which I was called bears this out: A., driving a lorry, ran into B., on a bicycle, and claimed that it was entirely B's fault. Fortunately, with the aid of valuable assistance, I was able to produce an exact diagram, drawn to scale, of the site of the accident in detail, showing the marks on the road caused by the wheels of the lorry and the bicycle, respectively. This was accompanied with the names of witnesses as to the accuracy of the measurements given. A's legal advisers, who had hitherto denied all responsibility, acknowledged their liability when they saw my diagram, and paid more than a thousand pounds as well as the costs of both sides in settlement of the case.

Prevention of Accidents

On the principle that prevention is better than cure, every step taken to diminish the number of accidents is of the greatest importance.

In 1918 I was asked, as Medical Officer to the Ministry of Munitions, to report on the wastage of working hours in

connection with accidents. I found that more hours were lost from carelessness than from any other cause. Not only does carelessness cause a very large number of accidents but carelessness in the shape of neglect to procure immediate treatment results in the loss of millions of hours and produces much unnecessary suffering. Septic inflammation of minor wounds is the direct result of neglect, and the main factor in this enormous and easily avoidable wastage of time. The trivial injury becomes converted into a serious lesion, involving perhaps the loss of a limb or even a life.

The Home Office records for 1908 to 1914, inclusive, show that, of the non-fatal cases coming under the Workmen's Compensation Act, over fourteen times as many cases of compensation last *more* than two weeks than continue *less* than two weeks. The exact figures are 215,-133 lasting less than two weeks, and 3,163,243 lasting more than two weeks. Later records corroborate these figures.

In the interests of the man and the manager, the employee and the employer, much may be done by the exercise of care and precaution to save unnecessary suffering and wanton wastage of time. Thus, by preventing the simple accidents from becoming serious, we shall avoid hours of pain, days of idleness and much worry and expense.

I hope later to refer to other points in connection with this extensive and important question of accidents.

THE CAUSATION OF INDUSTRIAL ACCIDENTS*

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IN order that we may be able to adopt the best remedial measures for the reduction and prevention of industrial accidents, it is essential that we should obtain as clear an insight as possible, not only into the various factors concerned in their causation, but into the relative degrees of importance to be attached to these factors. For instance, extreme fatigue undoubtedly increases the liability to accidents, and is a factor of great importance, but does the moderate degree of fatigue experienced by most industrial workers in the course of their normal working day exert any appreciable influence upon accident frequency? It is well known that accident frequency usually rises rapidly during the course of the morning spell of work, and in the last hour or last but one it may be from two to four times greater than that observed in the first hour of the spell (1). As a similar trend is often observed in the course of the afternoon spell, it is frequently concluded that these variations are due chiefly to fatigue. Another recognized factor in accident causation is the speed of production. In an analysis of about 50,000 accidents, made by the writer in 1918 for the Health of Munition Workers Committee (2), considerable stress was laid on this factor. Even more stress was laid on the mental state of the workers, and this psychical factor was spoken of as one of the most important in accident causation.

Further light upon the problem of accident causation has recently been adduced in a report of the Industrial Fatigue Research Board (3). In the first of the two investigations described, Mrs. Ethel E. Osborne and the writer discuss the accident data obtained over a period of a year at two munition factories. One of these factories, employing 1,800 workers, was devoted solely to the manufacture of 9.2-inch shells; the other, with 2,100 workers, to the manufacture of 6-inch shells. At both factories day and night shifts were worked during alternate weeks. At the 6-inch shell factory both men and women at first averaged 61 hours of work per week. Later on the women were changed from the two shift to a three shift system, and then they averaged only 39½ hours per week, or 21½ hours less than before, while the men continued on the same 61-hour week. In order to determine the effect of this change of hours on accident frequency, the number and incidence of the cuts treated at the surgery were investigated (these cuts forming over 70 per cent. of all the accidents incurred). In a three-month period, when the men and women were working the same 61-hour week, the women were found to experience 90 per cent. as many accidents as the men. The change of shift was effected gradually, and when it was completed, it was found that in the first three-month period under the altered system the women had 89 per cent. as many accidents as the men, while in the next three months they experienced only 67 per cent. as many. The latter figure is probably the more significant, as the previous figure must have been swollen

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by accidents due to the inexperience of the new women taken on to form the extra shift. We may conclude, therefore, that when the women were employed for an exceptionally long working week they experienced such fatigue that their accident frequency was about a third greater than when they worked an exceptionally short week.

steadily the whole night through. Evidently the factors responsible for this very different incidence in the two shifts cannot have been the same.

It is suggested by the authors of the report that the accident incidence of the day shift was controlled chiefly by the speed of production. The output of shells was determined by power load ob-

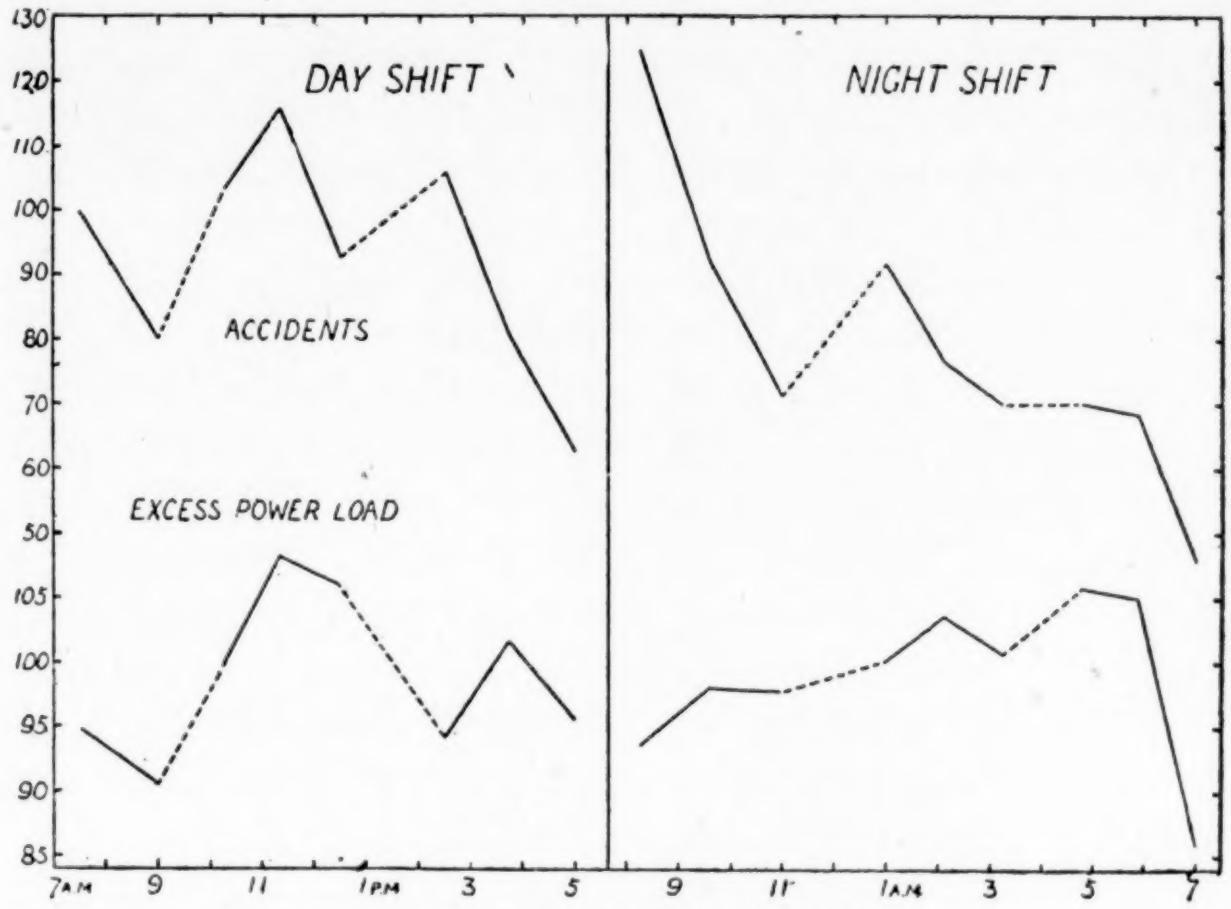

FIG. 1.—Accidents in relation to output.

In accordance with previous observations, the variations in accident frequency during the daily course of the work were much greater than the figure just mentioned. At the 9.2-inch shell factory, for instance, where both men and women worked a 48-hour day-shift week and a 60-hour night-shift week during alternate weeks, the cuts experienced varied from hourly rates of 116 to 68 by day, and of 113 to 54 by night, or roughly as 2 to 1. Their incidence is shown graphically in Figure 1, and it will be seen that the day shift accidents reached their maximum in the second spell of work, and fell rapidly in the third spell, while the night shift accidents, with one exception, fell fairly

servations, and the curve given in the lower part of Figure 1 shows a rough qualitative resemblance to the accident curve. It is not quantitative, as the output varied only between the extremes of 93 and 108, but as the writer has pointed out, with reference to fuse manufacture (2), a given increase of output may well cause even five or ten times as much increase in the number of accidents, because "the speeding-up has to be done mainly by quickening the rate at which the fuse part is clamped in, or unclamped from, the lathe, and the rate at which the cutting tools are changed and brought into contact with the metal surface. Not much speeding-up of the actual cutting operations is permissible, so

a given speeding-up of output means a relatively much greater speeding-up of the movements made at times when the workers are specially liable to knock their hands against the cutting tools."

The variations in the speed of production of the night shift workers have a rough resemblance to those of the day shift, showing a maximum in the middle hours and a minimum at the beginning and end. Although the speed of production must have affected the accident frequency, its influence was, however, almost entirely swamped by some other factor. This is believed to be mainly a psychical one. It is pointed out that when the day shift workers started work in the early morning, they were in a depressed condition, but that they brightened up gradually, especially after their tea and food at 9 A.M., and that they got into a more and more lively and careless state of mind as their dinner hour approached. The night shift workers, on the other hand, for the most part came to work in a lively and excited state, but they gradually calmed down during the night, as they had nothing to look forward to except an unexhilarating breakfast and bed. It is thought that these variations in the psychical state of the workers were chiefly responsible for the variations of accident frequency in the night shift, and to some extent also for those of the day shift.

This very different incidence of the day shift and night shift accidents confirms the more numerous results previously obtained at the fuse factory, and it is likewise supported by the observations made at a fuse factory in the United States (4). The night shift accidents were not recorded by the authors of the bulletin, as they were said to be "too small to yield conclusive data," but Dr. A. H. Ryan subsequently described them independently (5). The accidents incurred numbered 1,769, and their incidence shows a distinct fall during the course of the night. In the first three hours of the first work spell some of the numerous accidents were incurred by overtime day shift workers, but from the fourth hour onward there was no such complication. In the fourth and fifth hours of work the accidents (calculated per unit of output) were 100 and 104, respectively, but in the first four full hours of work of the second spell they fell to 85, 92, 92, and 89, respectively, or to about 12 per cent. less, in spite of the fact that the men had just worked a first spell of 5 2/3 hours' duration, followed by a meal period lasting only twenty minutes. In the twelfth hour of the night shift, however, the accident frequency increased distinctly, probably because of fatigue. In contradistinction to the night shift accidents, the day shift accidents showed the familiar rise from hour to hour of each spell.

The authors of the bulletin adduce other evidence in favor of the fatigue factor. This factor does undoubtedly exist and must always be borne in mind when considering accident causation, but the point at issue is not its existence, but its relative degree of importance. It is the opinion of the writer that the balance of evidence shows it to be of very little importance for most industrial workers. In the great majority of industries women can stand an 8-hour or a 9-hour day, and men a 10-hour day, without experiencing such physical fatigue as will appreciably affect their liability to accidents.

The second investigation described in the Industrial Fatigue Research Report (3) relates to laboratory experiments

made by Professor B. Muscio. Tests of the accuracy with which the center of a target could be pricked were made at half-hour intervals during the day, and it was found that the degree of accuracy steadily improved during the course of the morning, fell back almost to its original level after the midday meal, and improved again throughout the afternoon. There was never any diminution of accuracy toward the end of the morning or afternoon, so that the fatigue incident to the daily routine of work evidently did not diminish manual skill, and would not, under industrial conditions, have increased accident liability. As the work performed in the intervals between the tests was, however, mental, and not physical, it is difficult to interpret the results, but in another series of experiments a test involving a moderate degree of muscular activity (the pendulum test) was performed continuously for periods of two and one-half to three and one-half hours. In spite of the physical fatigue induced, the accuracy with which the test was performed increased throughout the experiment, although the rate of improvement decreased considerably after the first one and one-half hours. If this test is repeated by other subjects and for longer periods of time, and still fails to show that moderate fatigue induces loss of manual skill, it will afford valuable support to the foregoing doctrine.

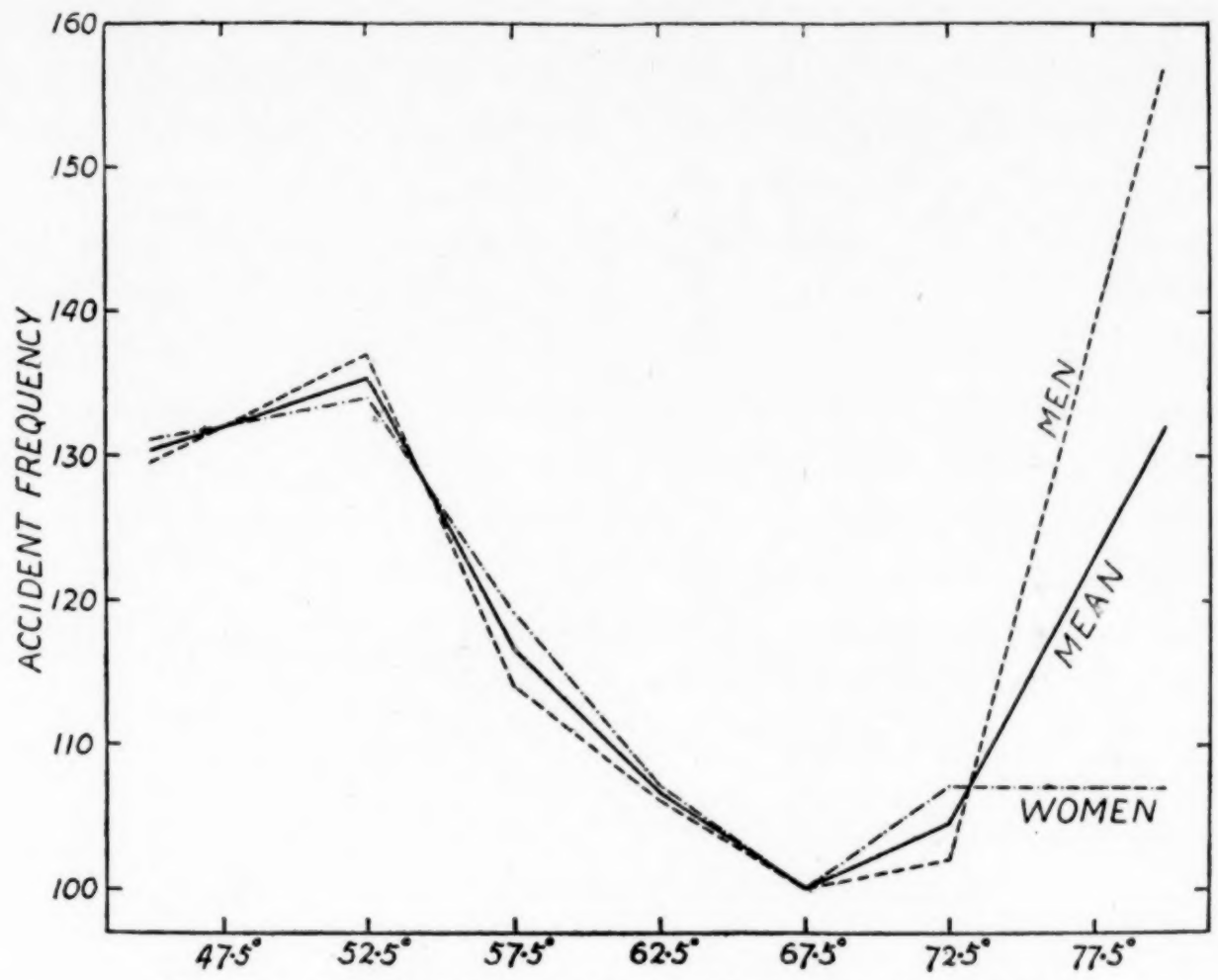

FIG. 2.—Accident frequency in relation to temperature.

In another section of the first investigation of the Industrial Fatigue Research Board Report mentioned (3), Mrs. Osborne and the writer describe the effect of temperature upon accident frequency. Continuous records of the temperature in the two shell factories were taken by means of thermographs, for periods of nine to twelve months. Combining the results obtained with the previous observations (for a six month period) which were made at the fuse factory, it was found that the optimum temperature with regard to accident immunity was 67°F. Figure 2 shows that the accident frequency gradually increased with

decreasing temperatures until at 52° it was 35 per cent. greater than at 67°. At 47° it was rather less than at 52°, possibly because the workers reduced their rate of production and thereby ran less risk of accidents; this is, however, only a surmise. At temperatures above 67° the accident frequency increased rapidly in the men, until at 77° it was 39 per cent. greater than at 67°, but the women showed only a 7 per cent. increase. This difference may have been due to the fact that the men were for the most part engaged on much heavier work than the women, and would on that account feel the heat more.

In all probability a temperature of 67° is too high for the maximum efficiency of workers engaged on fairly active work, but at the more suitable temperature range of 60° to 64°, accident frequency was only 6 per cent. greater than at 67°. It is therefore suggested that the standard temperature to be aimed at is 60° to 64° F.

Summary

1. Fatigue may cause a moderate increase of accident frequency when the hours of work are very long: *e. g.*, women shell-makers had 31 per cent. more accidents per working hour when on a 61-hour week than when on a 39½-hour week.

2. Probably fatigue has very little to do with the considerable increase of accidents which is generally observed during the course of the work spells. The rise is due chiefly to variations in speed of production, and to the psychical state of the workers.

3. Accidents were found to be at a minimum at 67° F., and to increase rapidly at lower and at higher temperatures. Thus, they were 35 per cent. more numerous at 52°, and 23 per cent. more numerous at 77°, than they were at 67° F.

BIBLIOGRAPHY

1. Committee on Fatigue from the Economic Standpoint. Brit. Assn. Rep., 1915, p. 325.
2. Vernon, H. M.: An Investigation of the Factors Concerned in the Causation of Industrial Accidents. Health of Munition Workers Committee. Memo. No. 21. London, H. M. Stationery Office, 1918.
3. Osborne, E. E., and Vernon, H. M.; and Muscio, B.: Two Contributions to the Study of Accident Causation. Indust. Fatigue Res. Board, Rep. No. 19, London, H. M. Stationery Office, 1922.
4. Goldmark, J., and Hopkins, M. D.: Studies in Industrial Physiology: Fatigue in Relation to Working Capacity. 1. Comparison of an Eight-Hour Plant and a Ten-Hour Plant. U. S. Pub. Health Ser., Pub. Health Bull. No. 106, Feb., 1920.
5. Ryan, A. H.: Discussion of Public Health Bulletin No. 106. Comparison of an Eight-Hour Plant and a Ten-Hour Plant. THIS JOUR., 1920-1921, *2*, 466.

J. I. H.
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ATMOSPHERIC PARTICULATE MATTER: I. DUST, WITH A NEW APPARATUS FOR ITS DETERMINATION*

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I. INTRODUCTION

THE hygienic significance of the many types of atmospheric particulate matter is a problem which is daily assuming more importance. Our ever increasing knowledge of the physiological action of dusts, fumes, and smokes emphasizes the need for more exact methods of determining their content in the air which we breathe, together with studies of their physical and chemical characteristics, such as the size and number of individual particles, the readiness with which they may be filtered, wetted, and flocculated, and the relation of these several factors to the abatement of nuisances and dangers caused by dusts, fumes, and smokes.

The literature contains many instances of financial saving resulting from the installation of industrial plants for the collection of metallurgical and acid fumes. Such plants were often installed to avoid committing a public nuisance, and the saving resulted in an unexpected but none the less acceptable financial return on the investment. Dusty gases, of a type difficult to handle in the laboratory, are cleaned in enormous quantities in the operation of the modern blast furnace, and the cleaned gases are used again in internal combustion engines. Many metallurgical and chemical operations require the cleaning of gases for use in another part of the process. The modern air washer removes a large portion of the particulate matter of the air. Often this particulate matter is of no hygienic significance and furnishes a purely local problem. The meteorologists, probably more than any other group, emphasize the importance of the fine particles in the air and require accurate methods for their determination.

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It is obvious, therefore, that the hygienist can draw on many sources of information outside his own field for methods of determining atmospheric particulate matter. We have made use of methods of established success, and, as a consequence, the apparatus to be described in this paper embodies many features derived from sources entirely remote from hygiene. Our efforts have been directed toward the development of a serviceable apparatus, the general principles of which may be adapted to laboratory and field use for quantitatively determining and for studying certain types of particulate matter in the air or in other gases. This paper is the first of a series from this laboratory dealing with the general question of the determination of atmospheric particulate matter and its relation to industrial problems of hygienic and physiological interest.

II. Classification of Atmospheric Particulate Matter

To attempt a classification which will satisfactorily cover this broad field is not the purpose of this paper. Particle size, however, appears to be a necessary consideration in making determinations both for comparative purposes and for exact quantitative analyses, and it is usually the deciding factor in the selection of a method of determination. Gibbs' (1) classification seems to be a most apt one, and is given in terms of colloid chemistry which are universally applicable. It presents a convenient distinction in the degree of dispersion of particulate matter on the basis of particle size:

(a) *Dusts,* in which the particles are larger than 10^{-3} cm. [10 microns] diameter. Such particles settle in still air with increasing velocity. They do not diffuse.

(b) *Clouds,* the particles of which range in diameter from 10^{-3} to 10^{-5} cm. [10 microns to 0.1 micron]. Such particles settle in still air at a constant velocity, depending upon their size, according to Stokes' law. They also do not diffuse.

(c) *Smokes,* the particles of which range from 10^{-5} to 10^{-7} cm. [0.1 to 0.001 micron] diameter. Such particles are in active Brownian motion and diffuse fairly rapidly. They do not settle at all in still air.

All three types are of importance to the hygienist. Frequently his problem will be complicated by fumes—such as lamp black, zinc oxide, or magnesium oxide—in which the individual particles tend to flocculate and even to grow in size, whereupon they behave much as if they were made up of larger units and are no longer true dispersoids. This is not an indication that Gibbs' classification is at fault, but merely illustrates the need of knowing the true physical state of the particulate matter in question. The line of demarcation between Gibbs' three classes is not, therefore, a perfectly definite one but there seems to be no need of attempting to make it so. It is quite sufficient to classify particulate matter according to the rate of settling and diffusion—a classification which is, in turn, based primarily on particle size.

Our respiratory system combines filtration with a high degree of humidification. The normal body temperature is appreciably higher than the air usually breathed. Consequently the temperature of the inspired air generally rises, the increase depending on the temperature of the initial air. This natural systemic defense against the introduction of particulate matter is fairly adequate against Gibbs' class A—dust which settles with acceleration—but, like any filtration device, it can be readily overloaded. It is inefficient, however, against class B, and is totally inadequate against class C.

J. I. H.
May, 1923

Both laboratory and industrial methods of handling these three types of particulate matter follow the same general reasoning, but it is illogical to attempt quantitative determinations of all three in terms of either the size, number, or weight of the particles simply because a method happens to be adapted to one particular class. Obvious limitations in methods are often imposed by the nature of the substance —that is, by its temperature, chemical action, volatility, hygroscopicity, inflammability, and explosive character—so that a given method may not be applicable although the general principle may afford a convenient industrial basis for avoiding the particular nuisance.

1. *Sampling*

In all analyses it is of primary importance to obtain a representative sample. If the substance in question is known to settle readily in comparatively still air, it is obviously necessary to take larger samples than in the case of true dispersoids—tobacco smoke, for example—which pass through such filtering media as fine texture filter paper, alundum crucibles, cotton, sugar filters, etc., and do not settle. In the case of a dispersoid like tobacco smoke, with which there is no apparent reason for rapid sampling, it is only necessary to take a sample large enough to weigh or to make whatever other determination is desired.

The same reasoning applies to methods of counting. A sensitive and highly accurate method, suited to counting particles which are small, uniform, and dispersed, may be unsatisfactory for making counts in a dusty factory or mine where the dust settles readily and is of mixed sizes. Equally unsatisfactory results may be obtained by using a less sensitive method, suitable for counting mine dust, for counting particles in comparatively pure air—a count of importance in meteorological work. The choice of a method for counting, therefore, depends upon the nature and size of the particles.

III. Dust

The term "dust" is used here to mean particulate matter of such size as settles in still air with increasing or uniform velocity. Dust, therefore, falls within Gibbs' classes A and B and consists of particles ranging in size from those easily seen through a hand lens down to those 0.1 micron in diameter. Particles of this size, while not visible through the ordinary microscope, are encountered in dusts and cannot be ignored, though their weight may be of little significance.

IV. A Review of the Literature

Although reviews of the methods proposed for the determination of particulate matter in the air have been published by Kershaw (2), Palmer, Coleman, and Ward (3), Hill (4), Knowles (5), Smyth (6), Bill (7), and others, it will facilitate the discussion and general interpretation of our data if we go over the ground briefly in this paper, including also several new methods which have been devised since the appearance of the latest reviews.

The classification of methods is based upon the manner of collecting the sample and not upon the subsequent procedure of analysis, as samples collected by various means can often be analyzed by like laboratory procedures: (1) settling, (2) counting, (3) filtration, (4) scrubbing and wetting, and (5) electric precipitation.

1. *Settling*

Miquel (8), in 1879, described a technic for exposing plates and counting, with the aid of a microscope, the particles which settled. Tissandier (9), in 1880, collected settled dust on an area of 2 square inches. Irwin (10), in 1902, determined soot fall by collecting and evaporating snow over an area of 100 square inches. Des Voeux and Owens (11), in 1912, made a like determination of soluble and insoluble matter by collecting the deposit in a trough with an area of 2 square feet. Mitchell (12) determined deposits of cement dust by making collections on vaselined plates and washing with gasoline. The Whipples (13) suggest a method, similar to that of Des Voeux and Owens, for recording air cleanliness in cities. Higgins, Lanza, Laney, and Rice (14) used settling methods for microscopic examination of silicious dusts. Monnett (15) advises methods of settling, filtration, and counting which are now in general use by the British in determining air pollution (16) and which have been studied by them in great detail.

Settling methods are a standard procedure in meteorological work and offer the great advantage of sampling over an extended period. Microscopic examination of dusts collected by settling directly on slides is not satisfactory since the particles usually pile and clump, and since the small ones, which settle less readily, may not be caught. As an index of soot or dust deposition over a given area, settling has a demonstrated and valuable application.

2. *Counting*

Coulier (17), in 1875, showed that fresh outdoor air, such as we ordinarily consider as clean and free from particulate matter, contained a vast number of minute particles which could be rendered visible in the form of a fog by suddenly reducing the pressure and thus causing the water vapor in the air to condense upon them. He further showed that the air could be freed of these fog-producing particles by filtering it slowly through cotton wool. Aitken (18), in 1887, apparently unaware of Coulier's earlier work, did considerable experimentation on this general problem and shortly afterward developed his now widely known *koniscope*. This apparatus seems to offer the most accurate counting method but it makes no distinction between fine and large particles, and is usually considered too sensitive for obtaining counts in air which contains readily weighable amounts of dust. Furthermore, the slightest trace of such substances as ammonium chloride, sulphuric acid fume, etc., produces extremely dense fogs. Aitken's method has, nevertheless, found application at the hands of a number of investigators (19) (20).

While sticky substances have been frequently employed as a means of fixing particles on a microscope slide as they chance to hit the slide, this practice is now of little but historical interest. Cave and his associates (21), in 1914, used a method of impinging a jet of dusty air on a sticky substance. About the same time Hill (22) produced a small, compact apparatus employing these principles, and calibrated its efficiency by placing the microscope slides, in their containing capsules, in series and obtaining a ratio between the counts on the several slides. Assuming that the slides would collect the particles with like efficiency—an assumption which he failed to justify—he estimated

the average efficiency of one slide to be about 62 per cent. (22) and recommended the use of this factor. This method of calibration, however, is fundamentally in error. Because one slide collects a certain percentage of the particles is no indication that the other slides should catch the percentage of particles missed by the first. Their respective tasks are different both in kind and in degree. Hill assumed that they were exactly similar.

Shortly after Hill's counter appeared, Innes (23) published an account of Kotzé's *konimeter,* an apparatus somewhat like Hill's but employing a smaller sample and a much higher orifice velocity. The Miners' Phthisis Prevention Committee of South Africa (24) recommends for this instrument an orifice velocity of 30 to 80 meters per second and as high as 130 meters per second in certain cases. The general method is carried further by Owens (16) (25), who uses no vaseline or other sticky substance on the cover-slip, humidifies the air sampled, and discharges it, by suction, through a narrow slot at a velocity comparable to that of sound (250 meters and over per second). He has shown that humidification produces Aitken's and Coulier's effects by the pronounced temperature and pressure drop at the orifice. The moisture thus condensed on the particles evaporates when the cover-slip is removed from the container. Owens uses 50-c.c. samples in determining atmospheric soot pollution, an amount which appears large for the determination of dust of hygienic significance.

It is interesting to compare these types of apparatus in the terminology of the respective inventors. Hill estimated his method as about 62 per cent. efficient for the dust in which he was interested. The Miners' Phthisis Prevention Committee of South Africa (24) believed that the konimeter caught practically all the dust particles, and estimated that Hill's device caught approximately 2 per cent. (Katz and Trostel (26) found the konimeter far more efficient than Hill's counter, while counts from the dust collected by the sugar tube were still higher.) Owens, using Kotzé's instrument, was able to collect only about 3 per cent. of the particles retained by his own apparatus, but he objects to Aitken's koniscope which, though it shows all the particles, gives no method for distinguishing between them.

Owens (27) suggests the use of his new instrument for obtaining standards of air dustiness for such purposes as determining the efficiency of air washers. Hill (28), in 1918, proposed his apparatus for this purpose and took dust counts at the entrance and exhaust of air washers, the ratio of the two counts giving an index of the efficiency of the washer.

Meyer's (29) method of counting dust particles was as follows: He introduced a sample of air into a Luer syringe containing a definite volume of water and, by shaking the syringe vigorously, brought the sample into suspension with the water. He then examined an aliquot portion microscopically, and counted the particles. If Coulier's fogging test is applied to this procedure, it will be seen how extremely difficult it is to wet fine particles by shaking alone.

To produce uniform aqueous suspensions of particulate matter it is usual to employ a stabilizer such as acacia, and to use a concentration of hydrogen-ion which will impede flocculation and settling. Otherwise one must count flocculates, the individual particles of which

are indistinguishable. This is especially true of fine particles such as pigments, clays, etc., and, to a large measure, of such notably non-adsorbent and chemically inactive substances as silica. These facts, which are recognized in the microscopy of pigments and clays, have received little or no attention in the counting or in the size measurement of dust particles.

A fume product such as zinc oxide consists of particles of about 0.4 to 0.6 micron (30). If one makes an aqueous emulsion of the collected fume and subjects this to microscopic examination, both the measurement and the counting of the particles are found to be difficult and impractical. A light fluffy powder such as talc dust is likewise difficult to count in aqueous suspension. Both substances are most difficult to float in well-dispersed air clouds owing to their marked tendency to flocculate and to roll up in clumps and balls even if the air for floating is well dried. If floated by air, their subsequent collection by filtration or other methods is far simpler than is the collection of freshly formed fume such as zinc oxide or ammonium chloride.

For these reasons we have not been satisfied with present methods for counting and for measuring particles which have been subjected to wetting such as occurs in the use of the sugar filter, Palmer's, or our own apparatus. Pigment microscopists are successfully photographing particles probably more difficult to disperse than those with which hygienists are concerned. They stress particle size rather than number as being easier to determine and easier for another investigator to check. A method of photographing atmospheric dust and other particulate matter as it actually occurs in the air would, in our opinion, be a most desirable addition to our present technic in this by no means simple field of research.

3. *Filtration*

The filtration methods which have appeared in the literature can be divided into two broad classes: (*a*) those employing insoluble filtering media and (*b*) those employing soluble filtering media.

a. Insoluble Filters.—Hesse (31), in 1882, used a cotton filter. Russell (32) filtered London air through glass wool and determined the carbon and nitrogen of the collected matter by combustion analyses. Arens (33) used cotton, and Cohen (34) added the practical refinement of weighing by tare. Fritzsche (35) used nitrocellulose as the filtering medium for chimney smoke, and estimated the collected matter by turbidimetry. Oliver (36) recommended the use of the cotton filter as employed by Haldane (37). Duckering (38), Harcourt (39), and Cohen and Ruston (40) have also used and described the cotton filter. Hubendick (41), Sargent (42), Messler and Brinker (43), Johannsen (44), and Nesbitt (45) have described various modifications of apparatus for determining particulate matter in gases, involving the filtration of the gas through filter paper and obtaining the increase in weight of the paper. Hahn (46) patented a method for determining the dust content of gases, involving their filtration through nitrocellulose, dissolving the nitrocellulose, and determining the dust content of the resulting mixture by turbidimetry. This method is frequently referred to in the literature. While it more properly belongs under *soluble filters,* it is placed here since Fritzsche (35) used the same filtering medium. Simon (47) filtered blast furnace gas through an extraction

thimble. For this same purpose Brady and Touzalin (48) and Touzalin (49) used a Soxhlet extraction thimble. They emphasized the importance of drawing the sample through the filter at a rate within 2 to 3 feet per second of the gas velocity in the pipe from which the sample was taken, claiming that the results would be considerably in error unless this precaution were observed. Dunn (50) has taken specific exception to this point in a large scale method in which he filtered smelter flue gas through asbestos bags, measured the gas flow by pitot tube, and determined the increase in weight of the bag. Todd (51) obtained comparative data on schoolroom air by filtering it through flannel disks and comparing the coloration obtained with that of an empirical set of standards.

Owens' filtration method (52) of determining air pollution is somewhat similar to Todd's, and involves filtration through a portion of filter paper, measuring 1/8 inch in diameter, of which the filtration efficiency is calibrated. Owens' more recent continuous recording filter now used by the British has been described by McKay (16), who has pointed out that its records are in a measure dependent on the color of the collected matter. Anderson and Armspach with Armspach and Ingels (53) have recently suggested a method of filtering through cloth disks of known resistance, as shown by a manometer across the two sides of the disk, and obtaining an index of air dustiness by the gradual increase of this resistance as air passes through the filtering medium.

b. Soluble Filters.—Whether used for the determination of air dust or of bacteria, soluble filters function in the same general manner, regardless of the filtering medium. While sugar has been most used, resorcinol, ammonium oxalate, salt, and other substances have been suggested. In all cases the air or gas to be examined is drawn through the apparatus, the filtering media dissolved in a suitable solvent, usually water, and the substance to be determined caught by a second filtration or estimated by other methods.

Möller (54), in 1894, although he was not the originator of the method, used the sugar filter for filtering out bacteria in the air. His device consisted of 50 mm. of finely powdered sterilized sugar on a layer of three filter papers. As the resistance was high he took only 1-meter samples of air, measured the air volume by gas-meter, dissolved out the sugar with sterilized water, and then counted the bacterial colonies grown on gelatin in the usual manner. For determining dust he used the dry filter-paper method. Soper (20) used the sugar filter in making dust determinations in the New York subway system. His apparatus was much like Möller's; Möller, however, corrected for variations in pressure on his gas-meter while Soper seems to have ignored this point.

The Miners' Phthisis Prevention Committee of South Africa (24) (55), Johnston (56), Laschinger (57), Gray (58), and Boyd (59) suggested modifications of this general method. Laschinger appears to have metered pulsating air flow through a flat orifice with the two pressure taps equidistant from the orifice. This method is decidedly inaccurate unless the meter used has been previously calibrated, with the utmost care, against an accurate meter. These investigators, most of whom were members of the Phthisis Commission or directly concerned in its general investigations, undoubtedly have used the most careful and exact method in the determination of silicious dust in its relation to the production of fibrosis of the lungs.

They emphasize the value of both counting and gravimetric methods, neither of which should be used alone. Their method of grading particle size by elutriation is particularly apt, while the complete data which they furnish on size-frequency counts of silica particles constitute the only thorough attempt of the kind that we have seen.

In this country the sugar tube has been much used, especially by the Bureau of Mines, which recommends its use for such material as insoluble rock dusts. Several bulletins and technical papers have been published by the Bureau of Mines and by others, of which the most pertinent seem to be those by Lanza and Higgins (60), Watkins (61), Selvig, Osgood, and Fieldner (62), Baskerville (63), a brief report of an investigation of granite dust (64), and a splendid paper by Fieldner, Katz, and Longfellow (65), which contains the first attempt, as far as we have been able to discover, to calibrate the sugar-tube method in terms of its filtration efficiency. Heretofore, its efficiency had been determined by connecting two tubes in series and determining the weight of dust caught in both tubes. While one may not agree with the emphasis placed on the determination of particles less than 1 micron in size, their general method can be adapted to the determination of filtration efficiencies of many other media. The general method of calibration and arrangement of apparatus is much the same as that which they used previously in calibrating the efficiency of the Palmer apparatus (66), but their gravimetric test is less severe. In this earlier paper they present a method of determining "optical efficiency" based on matching Tyndall light beam intensities on the exhaust air from the Palmer apparatus against an arbitrary standard of which the intensity could be varied at will by dilution with known amounts of filtered air. Tobacco smoke and finely ground silica dust were used in the optical calibrations of both the Palmer and the sugar-tube apparatus. Their gravimetric method utilized, in the first instance, a small Cottrell precipitator through which fractional portions of the dusty escape air from the Palmer apparatus were passed, and the dust caught and weighed on aluminium foil. The dust which entered the Palmer apparatus first passed through a cotton filter and must, therefore, have been excessively fine. In the second instance, a small dust cloud producer was used in which the amount of dust introduced into the sugar tube could be obtained by the difference in weight of the cloud producer before and after a determination. This weight was checked against the dust recovered in the sugar tube, and the filtering efficiency of the latter thus determined.

c. Discussion of Filtration Methods.—Filtration devices in general have the great advantage of extremely simple technic, which is essential in field work, as compared with the more delicate technic required in methods which necessitate washing the dust-collecting apparatus. Also, they offer a wide range in filtration efficiency and permit the selection of apparatus best suited to the problem. No such selection is permissible with an instrument such as Palmer's. Filtration methods are especially applicable in the determination of particulate matter which is affected by water or heat, or is explosive, inflammable, etc. Frequently shorter routine methods, such as turbidimetry and other optical means, can be standardized by a series of filtration determinations, and the objectionable operations of drying and weighing can thereby be avoided. An advantage in the sugar-tube technic, em-

ployed by the Bureau of Mines, is the use of long non-collapsible rubber tubing to connect the pump and sugar tube so that the latter can be placed wherever desired. We have utilized this feature with other types of dust filters, especially those requiring a powerful pump too heavy to carry about.

Disadvantages in the use of filtration, particularly for dusts which settle with acceleration, are the small size of the sample and the slow rate of speed with which the sample must be taken in order to obtain efficient filtration. The sugar-tube method is also objectionable because of the second filtration required. Another objection, which seems to us of no importance but which is sometimes raised regarding this method, is the necessity of correcting for the insoluble matter in the sugar. A number of determinations are always made together so that the correction can be applied by tare. Filtration devices, particularly those of small cross-sectional area, in which the dust or fume to be determined rapidly increases the resistance of the filter, record progressively increasing inaccuracies in the measurement of air flow unless they are previously calibrated with considerable care. Any device which regulates the air flow, such as that used by the Bureau of Mines (65) (66), will correct this difficulty, but such corrections are not easy in field tests; and the use of either a wet or a dry gas-meter or any other integrating recording flow meter, though also obviating the trouble, complicates the apparatus and often makes it too cumbersome for field work. The Bureau of Mines specifically recommends waiting, at the end of the suction stroke of their hand pump, for the pressure to come to equilibrium, in order to avoid errors due to pressure differences. Such errors, however, are difficult to avoid in the usual type of positive mechanically operated suction pumps.

Since the sugar tube must be held with the sugar surface horizontal, it collects dust falling in by gravity as well as dust which is drawn in by suction. If samples are taken at the low rates normally used—1 cubic foot per minute—the dust which enters the tube by settling will reach appreciable proportions, particularly in tubes as wide as those used by the Bureau of Mines, namely, 2⅜ inches. In using the sugar tube, therefore, it seems to us less important to measure air flow accurately, than in methods where dust is not introduced into the collecting device by settling.

d. Fogging Test for Filtration Efficiency.—As a sensitive test for filtration efficiency in both field and laboratory work, it is often convenient to use Coulier's test in much the same manner as Hill's (4) method of diffraction is used. A suitable flask is placed between the filter and the pump, and reduced pressure is applied to the flask with the aid of a three-way cock. A fog indicates that particulate matter has passed through the filter. Hill increased the effect by focusing a light beam through the flask, thus increasing the visibility of the fog. As the fog-producing power of air may be due to causes other than particulate matter (67, p. 276), this test is not applicable to electric precipitation although particulate matter may have been quantitatively removed.

4. *Scrubbing and Wetting*

Because of the ease with which many gases can be absorbed by bubbling them through a liquid, it is but natural that numerous modifications of this general principle have been applied to the determination of air dust. Modifications of

bubbling methods have been proposed, usually with the object of increasing the contact between the liquid and the gas or the particulate matter which the gas is carrying along. Tissandier (68), in 1874, proposed the determination of atmospheric dust by aspirating through distilled water in Liebig bulbs, using a U-tube containing a plug of cotton as a check against imperfect stoppage of the dust in the bulbs. Arens (33) claimed 85 per cent. efficiency for a method whereby the air entered at the bottom of a vessel and was scrubbed by a downcoming stream of water, contact being improved by staggered baffle plates which sloped from the side down toward the center. Tooms (69) determined silica dust in the South African mines by bubbling it through water. Palmer and his associates (3) (70) developed a combination bubbling and spraying method which has been much used, particularly in this country. This apparatus, which is too well-known to need description here, received the general endorsement of the Public Health Service (71) with a reservation pending the development of more accurate methods (72). Running comparative field tests against a Cottrell precipitator, Bill (7) found the efficiency of the Palmer apparatus to be 63 per cent. for certain dusts, while Katz, Longfellow, and Fieldner (66) showed its gravimetric efficiency to be 45 per cent. against fine silica dust. Smyth and Iszard (73) criticize the methods used by Bill and by Katz and his associates as being too severe, particularly the *optical method*, used by the latter group, which they believe tends to over-emphasize the particles less than 1 micron in size. This criticism is irrelevant, however, in view of the fact that although Katz and his associates established the fundamental principle that the Palmer apparatus was unsuited for the determination of fine particles (less than 1 micron in size), they in no sense implied that this apparatus was unsatisfactory for the determination of dusts of larger sizes. Smyth and Iszard also point out that fine dust suspensions in water should be evaporated to dryness and should not be filtered. Possible errors from this source are noted in the subsequent work of the Bureau of Mines (65). Trostel (74) has recently shown the Palmer apparatus to be about 98 per cent. efficient for determining certain dust particles ranging in size from 5 to 150 microns.

A method recently developed by Greenburg and Smith (75) involves bubbling dusty air through water. Since their apparatus appears to be based on the same principle as ours, it will be discussed elsewhere in this paper.

5. *Electric Precipitation*

An ever increasing number of industrial applications of the Cottrell precipitator testify to successful handling of many substances such as metallurgical and sulphuric acid fumes. Other methods, however, have frequently been found to be more suitable. The application of electric precipitation to the determination of the general types of particulate matter under discussion has been the subject of several papers which show that a portable apparatus is perfectly feasible for small samples.

It is our opinion that electric precipitation is more applicable to the determination of fume and smoke products—substances which are far more uniform than dust and which therefore do not require as large samples—than to the determination of non-uniform dusts such as silica, which settle with acceleration

or evenly and which do not diffuse. The facility with which fumes and smokes generally pass through filters such as paper, alundum crucibles, sugar filters, etc., depends on the physical characteristics of the particles and on the degree of their dispersion. Electric precipitation is well adapted to the determination of the majority of smokes and fumes.

If one is willing to accept this viewpoint, the adaptation of electric precipitation to field work of this type is comparatively simple. At the present time we are using two sizes of precipitating apparatus, one of which is rated in liters or cubic centimeters per minute and the other in cubic feet. The smaller apparatus is portable, but the problem of making the larger one easily portable is yet to be worked out. The latter type will be used for comparative field and laboratory tests with our own apparatus which is described elsewhere in this paper.

V. The Wetting of Fine Insoluble Powders with Water

So many commercial methods of collecting dust and fume by wet scrubbing methods, in which water is the scrubbing liquid, are in successful operation, that it occurred to us that the principle could be applied to the quantitative determination of air dust. The general method has an advantage over filtration methods in that large samples can be taken rapidly—a feature which is desirable in dealing with dusts or other matter that settles with comparative rapidity. Furthermore, it materially reduces the time spent in field work.

The readiness with which particulate matter in general adapts itself to wetting does not depend upon particle size alone. The physical state of the particles, the wetting medium, the method by which contact between the wetting medium and the particles is obtained, and the duration of this contact must also be taken into consideration. For example, ammonium chloride fume, which passes readily through water in gas-washing bottles, can be quantitatively recovered by bubbling it through an alundum crucible immersed in water (76). This combines filtration and wetting. Engler and Wild (77) showed that phosphorous pentoxide fume passed through a number of wash bottles; yet phosphorous pentoxide is one of the most hygroscopic substances known. It has been pointed out, however, that determinations of dust based on the wash-bottle method are inaccurate since all the dust is not retained.

Ehrenberg and Schultze (78) attribute the difficulty in wetting dusts—and it seems to apply equally to fumes and to smokes—with water to an air film of ultramicroscopic dimensions which surrounds each particle and thus prevents its touching the water. Bancroft (67, pp. 21 and 72) explains this in terms of surface tension, and suggests that any process which reduces this film of adsorbed air renders the dust easier to wet.

1. *The Significance of the Charge Carried by Dust Particles*

Rudge (79) showed that the majority of the particles of dust clouds were charged either positively or negatively. Metallic elements and basic oxides were found to have a negative charge, while non-metallic elements and acid-forming oxides gave a positive charge—the opposite to that shown by the ions of these substances in solution. Lamoreaux (80) presents an explanation of the high efficiency of the Feld scrubber for "metallurgical smoke," consisting principally

of negatively charged particles, on the basis of the mutual attraction of these negatively charged particles and the positively charged particles of the fine mist produced by rotating the movable parts of the scrubber. In any scrubbing method for the recovery of dust, fume, or smoke we are dealing with particles of microscopic dimensions and often with particles of less than microscopic dimensions. This is true both of the particles to be scrubbed and of the scrubbing medium. Consequently, in order to utilize any such possible forces of attraction between the dust and the water spray, particles of unlike signs must, to quote Lamoreaux, "be brought within their radii of action." Since fine spray has been shown to be charged positively (81), and drops of larger size are charged negatively, a mixed dust scrubbed by a method producing water particles of mixed sizes is subjected to intimate contact with drops having a charge of either sign or of both.

The tendency to adsorb moisture must be considered in relation to this question of particle charge. In this connection Briggs (82) determined the adsorptive properties of quartz dust (at 30° C.) and concluded that the slight but definitely determinable amount of moisture taken up was due to the mutual attraction between silica particles and water vapor—an attraction which he showed existed in atmospheres below the saturation point. In view of the fact that humidification and wet methods in general are frequently employed in mines and other places with dust hazards for the alleviation of dust nuisances, it is surprising that more work has not been done on this fundamental problem. Such studies, for example, as the adsorptive properties of silicious and other dusts, the effect of adsorption on the readiness with which the particles can be wetted, the effect of such adsorption on the production of dust clouds, and the best methods by which these clouds can be flocculated, filtered, etc., would form valuable contributions.

Lamoreaux found, as one would expect, that a substance like zinc oxide powder, in which the particles are negatively charged, is more easily recovered by spraying than is silica, in which the particles are positively charged. It is hard to show this in the laboratory because of the difficulty in producing dust clouds of definite intensity and of definite particle size. Hill and Armspach (83) showed that spraying dusty air as it passed through a modern air washer was an inefficient method of removing dust, and that satisfactory collection of dust depended upon the violent change in direction and intimate wetting contact achieved in the entrainment separators at the exhaust end of the washer. There is no doubt that simple spraying will remove much of the dust just as rain removes dust from the air, but to make such spraying comparable to methods utilizing intimate contact and abrupt directional changes appears to be impractical.

Commercial scrubbers and air washers have the great advantage over laboratory apparatus in that the amount of water used is of minor importance. It is, however, of the greatest importance in our work since it would be useless, for analytical purposes, to collect a few milligrams of dust in a gallon of water when satisfactory results can be obtained far more simply by direct filtration methods. Laboratory scrubbing methods which involve supplying a continuous stream of water seem to be less applicable than methods which use but a small amount of water, although the

latter might well be the more efficient.

2. *The Use of Foam Producers*

A principle which is mentioned by Lamoreaux (80) and Bancroft (67, p. 132) is the use of substances which alter the surface tension of the wetting medium and induce the formation of tiny bubbles. Among the substances which give this effect with water, when air is passed through, as in our apparatus, are ether, caprylic alcohol, sodium oleate, and saponin. Common soap and soap powders produce like effects but to a markedly less degree. Saponin appears to be the most powerful and best adapted to our work. A few drops of very weak saponin emulsion or suspension in water produces a strong foaming effect, while too much saponin results in the foamy water being carried past the spiral. Powerful adsorbents like carbon soon take up the foam producers and the foaming subsides. Most dusts, however, seem to have little or no effect on saponin foaming.

The mere fact that such foaming agents facilitate cleaning results in obtaining, as a general rule, higher recoveries than are ordinarily possible, yet our figures show no appreciable difference with or without saponin in collecting talc and silica. Watching the myriads of tiny foam bubbles produced by the presence of a few drops of 2 per cent. saponin, one would feel certain that the wetting efficiency was greater.

The weight of the saponin added to the water in the collectors is negligible, but for extreme accuracy like amounts can be added to the tare and errors from this source can thus be eliminated. Evaporation to complete and thorough dryness is not hindered by the use of small amounts of saponin. Volatile foam producers like ether and caprylic alcohol are unsatisfactory since they are rapidly blown out of the water.

While water is the only liquid which has been extensively used so far, we are by no means convinced that it is the most suitable wetting medium. It has long been recognized by paint and pigment manufacturers that certain oils exert selective adsorption (67, p. 88); thus some oils wet pigments more readily than does water—linseed oil, for example, displaces moisture on white lead particles, rendering perfect drying unnecessary before the lead is mixed with the oil. The same reasoning may apply to wetting dusts, that is, other liquids may do it more readily than does water.

VI. The Production of Dust Clouds

In making comparative studies of existing or of new apparatus for the determination of atmospheric dust it is essential to use equipment which will give results representative of conditions met in field tests. If the laboratory method makes a more severe test than do field conditions, it causes errors on the safe side. The methods used by the Bureau of Mines are the most satisfactory from our point of view, and it is these methods with a few modifications which have been used in this investigation.

The Bureau of Mines (65) (66) found it best to use silica dust dried at 200 to 300° C. and dry air in order to produce satisfactory clouds, and this, in general, agrees with our experience. We have used both types of dust floaters described by them, one of which is shown in Figure 3. Since we have been concerned with dust clouds produced over periods as long as one-half hour, it has been found best to rap the tapered portion of the

dust floaters with the protected clapper of a powerful electric bell. This gives a more uniform cloud than is obtained by simply blowing air through and occasionally rapping the floater, and it also greatly assists in floating only the smaller particles. In any case the dust and the tube must be cooled to room temperature, otherwise the dust will be deposited on the upper and cooler portions of the tube, and non-uniform clouds will result. This is the thermal filtration phenomenon of Aitken (84) and Bancroft (85).

The methods used by Palmer, Coleman, and Ward (3) and Bill (7), whereby dust is allowed to fall directly into the apparatus, result in producing clumps and flocculates of dust which are far too easy to recover. Trostel(74) sampled through bolting cloth but he was using dust containing particles of 5 to 150 microns, so that clumping was of less importance. A method which we have often used is to allow the dust to pass through the finely constricted apex of a glass funnel by rapping the apex with the clapper of a bell—the clapper, in this case, being unprotected, as violent rapping is required with narrow funnels. By this means clouds which are constant within 5 to 10 per cent. of each other are produced over five-minute periods. Clumps are formed also, but they are easier to recover than the normal air-floated clouds encountered in the field.

(To be continued)

BIBLIOGRAPHY

1. Gibbs, W. E.: The Industrial Treatment of Fumes and Dusty Gases. Jour. Soc. Chem. Indust., 1922, *41*, 189T.
2. Kershaw, J. B. C.: Dust, Soot and Smoke. Cassier's Mag., 1911, *39*, 250.
3. Palmer, G. T., Coleman, L. V., and Ward, H. C.: A Study of Methods for Determining Air Dustiness. Am. Jour. Pub. Health, 1916, *6*, 1049.
4. Hill, E. V.: Quantitative Determination of Air Dust. Heating and Ventilating Mag., 1917, *14*, 23.
5. Knowles, E. R.: Dust Determinations in Air and Gases. Jour. Am. Soc. Heating and Ventilating Eng., 1919, *25*, 67.
6. Smyth, H. F.: A Critical Review of Methods for the Study of Dust Content of Air. THIS JOUR., 1919-1920, *1*, 140.
7. Bill, J. P.: The Electrostatic Method of Dust Collection as Applied to the Sanitary Analysis of Air. THIS JOUR., 1919-1920, *1*, 323.
8. Miquel, P.: Etude sur les poussières organisées de l'atmosphère. Ann. d'hyg., 1879, S. 3, *2*, 226, 333.
9. Tissandier, G.: Les poussières de l'atmosphère. Rev. sci., 1880, S. 2, *18*, 814.
10. Irwin, W.: The Soot Deposited on Manchester Snow. Jour. Soc. Chem. Indust., 1902, *21*, 533.
11. Des Voeux, H. A., and Owens, J. S.: The Sootfall of London: Its Amount, Quality, and Effects. Lancet, 1912, *1*, 47.
12. Mitchell, J. P.: Determination of Dust Fall in the Neighborhood of Cement Plants. Jour. Indust. and Engin. Chem., 1914, *6*, 454.
13. Whipple, G. C., and Whipple, M. C.: Studies in Air Cleanliness. Jour. Am. Soc. Heating and Ventilating Eng., 1915, *21*, 211.
14. Higgins, E., Lanza, A. J., Laney, F. B., and Rice, G. S.: Siliceous Dust in Relation to Pulmonary Disease among Miners in the Joplin District, Missouri. U. S. Bur. Mines, Bull. 132, 1917.
15. Monnett, O.: Determination of Atmospheric Impurities. Chem. Met. Engin., 1920, *23*, 1117, 1173.
16. McKay, R. J.: Recent Progress in Smoke Abatement and Fuel Technology in England. Mellon Inst. Indust. Res. Smoke Investigation, Bull. 10, 1922.
17. Coulier: Sur une nouvelle propriété de l'air. Jour. de pharm., 1875, *22*, 165, 254.
18. Aitken, J.: On the Number of Dust Particles in the Atmosphere. Tr. Roy. Soc. Edin., 1887-1888, *35*, 1.
19. Macfayden, A., and Lunt, J.: Bacteria and Dust in Air. Tr. Brit. Inst. Prev. Med., 1897, *1*, 142.
20. Soper, G. A.: The Air and Ventilation of Subways. New York and London, John Wiley & Sons, 1908.
21. Cave, C. J. P., et al.: First Report of the Committee for the Investigation of Atmospheric Pollution, April, 1914 to March, 1915.

J. I. H.
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Reviewed in Analyst, 1916, *41*, 113.

22. Hill, E. V.: Ventilating Division of the Health Department, Chicago, Ill. Jour. Am. Soc. Heating and Ventilating Eng., 1913, *19*, 421.
23. Innes, J.: The Estimation of Injurious Dust in Mine Air by the Kotzé Konimeter. Jour. Chem. Met. Min. Soc. S. Africa, 1918, *18*, 199; 1919, *19*, 132.
24. Final Report of the Miners' Phthisis Prevention Committee of South Africa. Pretoria, 1919.
25. Owens, J. S.: Suspended Impurity in the Air. Proc. Roy. Soc., 1922, S. A, *101*, 18.
26. Katz, S. H., and Trostel, L. J.: Comparative Tests of Air Dustiness with the Dust Counter, Konimeter and Sugar Tube. Jour. Am. Soc. Heating and Ventilating Eng., 1921, *27*, 519.
27. Owens, J. S.: Atmospheric Dust. Jour. Soc. Chem. Indust., 1922, *41*, 438R.
28. Report of Committee on Standard Method of Testing Air Washers. Jour. Am. Soc. Heating and Ventilating Eng., 1918, *24*, 69.
29. Meyer, A. L.: A Method for Determining the Finer Dust Particles in Air. THIS JOUR., 1921-1922, *3*, 51.
30. Green, H.: A Photomicrographic Method for the Determination of Particle Size of Paint and Rubber Pigments. Jour. Franklin Inst., 1921, *192*, 637.
31. Hesse, W.: Quantitative Staubbestimmungen in Arbeitsräumen. Dingler's polytech. Jour., *240*, 52 (abstracted in Ztschr. f. anal. Chem., 1882, *21*, 285).
32. Russell, W. J.: On the Impurities in London Air. The Monthly Weather Report of the Meteorological Office, England, August, 1885. (From Cohen and Ruston (40).)
33. Arens, C.: Quantitative Staubbestimmungen in der Luft nebst Beschreibung eines neuen Staubfängers. Arch. f. Hyg., 1894, *21*, 325.
34. Cohen, J. B.: A Method of Estimating the Weight of Solid Matter in the Air. Jour. Soc. Chem. Indust., 1897, *16*, 411.
35. Fritzsche, P.: Colorimetrische Rauchdichtebestimmung. Ztschr. f. anal. Chem., 1898, *37*, 92.
36. Oliver, T.: A Lecture on the Diseases of the Lung Caused by Dust. Jour. Prev. Med., 1905, *13*, 317.
37. Foster, C. LeN., and Haldane, J. S.: The Investigation of Mine Air. London, Chas. Griffin, 1905, pp. 51, 120.
    Haldane, J. S.: Methods of Air Analysis. London, Chas. Griffin & Co., Ltd., 1918, p. 131.
38. Duckering, G. E.: Special Report on Methods of Determination of Dust and Lead in the Air of Workrooms. Ann. Rep. Chief Inspector Factories and Workshops for the Year 1910. London, p. 201.
    Duckering, G. E.: Report of the Departmental Committee Appointed to Inquire as to Precautions for Preventing Danger of Infection from Anthrax in the Manipulation of Wool, Goat Hair, Camel Hair, etc. London, 1918, p. 96.
39. Harcourt, A. V.: Report of the Departmental Committee Appointed to Inquire into the Dangers Attendant on the Use of Lead and the Danger of Injury to Health Arising from Dust and Other Causes in the Manufacture of Earthenware and China, etc. Appendices, *2*, 120. London, 1910.
40. Cohen, J. B., and Ruston, A. G.: Smoke, a Study of Town Air. London, Edward Arnold, 1912, p. 12.
41. Hubendick, E.: Staubbestimmung in Hochofengasen. Abstracted in Ztschr. f. angew. Chem., 1906, *1*, 350.
42. Sargent, C. E.: The Testing of Inflammable Gases. Iron Trade Rev., 1907, *40*, 78; Jour. Am. Soc. Mech. Eng., 1906, *28*, part 2, 815.
43. Iron Age, 1908, *81*, 1687.
44. Johannsen, O.: Ueber Staubbestimmungen im Gichtgas. Stahl u. Eisen, 1912, *32*, 16.
45. Nesbitt, C. T.: A Simple Apparatus for Estimating Dust in Gas. Chem. News, 1912, *106*, 235.
46. Hahn, M.: Process for the Rapid Determination of the Dust Content of Technical Gases. German Patent No 201,789 (1907). Abstracted in Jour. Soc. Chem. Indust., 1908, *27*, 1144.
47. Simon, J.: Ein neuer Apparat zur Bestimmung des Staub- und Wassergehalts in Abgasen. Stahl u. Eisen, 1905, *25*, 1069.
48. Brady, W., and Touzalin, L. A.: Determination of Dust in Blast-Furnace Gas. Jour. Indust. and Engin. Chem., 1911, *3*, 662.
49. Touzalin, L. A.: Apparatus for Determining Dust and Moisture in Gases. U. S. Patent No. 984,047 (Feb. 14, 1911).
50. Dunn, E. M.: Determination of Gases in Smelter Flues; and Notes on the Determination of Dust Losses at the Washoe Reduction Works, Anaconda, Montana. Tr. Am. Inst. Min. Eng., 1914, *46*, 648.
51. Todd, J. B.: A New Method of Determining the Dust in Air and in Fresh Air Schoolrooms. N. Y. Med. Jour., 1914, *99*, 426.
52. Advisory Committee on Atmospheric Pollution. Report on Observations in the Year 1916-1917. Lancet, 1918, *1*, Supplement to March 23.
53. Armspach, O. W., and Ingels, M.; Anderson, F. P., and Armspach, O. W.: Standard Method of Testing Dust Removal Efficiencies of Air Washers with a New Method of Making Air Dust Determinations. Jour. Am. Soc. Heating and Ventilating Eng., 1922, *28*, 533.

54. Möller, K.: Quantitative Bestimmung des Staubgehaltes der Luft. Gsndht. Ing., 1894, *17*, 373.
55. General Report of the Miners' Phthisis Prevention Committee of South Africa. Pretoria, 1916, p. 20; Appendix, p. 66.
56. Johnston, A. McA.: Note on Dust Determination by Filtration through Sugar. Jour. Chem. Met. Min. Soc. S. Africa, 1911-1912, *12*, 442; 1912-1913, *13*, 150.
57. Laschinger, E. J.: New Apparatus for Sampling Air for Dust. Jour. Chem. Met. Min. Soc. S. Africa, 1911-1912, *12*, 443.
58. Gray, J.: A New Type of Dust Collecting Tube. Jour. Chem. Met. Min. Soc. S. Africa, 1912-1913, *13*, 186.
59. Boyd, J.: Sampling of Dust in Mine-Air. Engin. and Min. Jour., 1919, *107*, 395.
60. Lanza, A. J., and Higgins, E.: Pulmonary Disease among Miners in the Joplin District, Missouri, and its Relation to Rock Dust in the Mines. U. S. Bur. Mines, 1915, Tech. Paper 105.
61. Watkins, J. A.: Occurrence and Mitigation of Injurious Dusts in Steel Works. U. S. Bur. Mines, 1917, Tech. Paper 153.
62. Selvig, W. A., Osgood, F. D., and Fieldner, A. C.: Collection and Examination of Rock Dust in Mine Air. U. S. Bur. Mines, 1920, Rep. Investigations 2122.
63. Baskerville, C.: Apparatus for Taking Dust and Bacteria Samples of Air. Jour. Indust. and Engin. Chem., 1914, *6*, 238.
64. Investigation of Dust in the Air of Granite-Working Plants. U. S. Bur. Mines, 1921, Rep. Investigations 2213.
65. Fieldner, A. C., Katz, S. H., and Longfellow, E. S.: The Sugar-Tube Method of Determining Rock Dust in Air. U. S. Bur. Mines, 1921, Tech. Paper 278.
66. Katz, S. H., Longfellow, E. S., and Fieldner, A. C.: Efficiency of the Palmer Apparatus for Determining Dust in Air. THIS JOUR., 1920-1921, *2*, 167.
67. Bancroft, W. D.: Applied Colloid Chemistry. London, McGraw-Hill Book Co., Inc., 1921.
68. Tissandier, G.: Les poussières atmosphériques. Compt. Rend., 1874, *78*, 821.
69. Penlerick, S.: Ventilation and Health Conditions in the Mines of the Witwatersrand, with Special Reference to the Ventilation System of the East Rand Proprietary Mines. Jour. Chem. Met. Min. Soc. S. Africa, 1910-1911, *11*, 60.
70. Palmer, G. T.: A New Sampling Apparatus for the Determination of Aerial Dust. Am. Jour. Pub. Health, 1916, *6*, 54.
Smyth, H. F., and Miller, T. G.: A Hygienic Survey of Cigar Manufacturing in Philadelphia. Med. and Surg., St. Louis, 1917, *1*, 698.
Miller, T. G., and Smyth, H. F.: The Dust Hazard in Certain Industries. Jour. Am. Med. Assn., 1918, *70*, 599.
Winslow, C.-E. A., Greenburg, L., and Angermyer, H. C.: Standards for Measuring the Efficiency of Exhaust Systems in Polishing Shops. U. S. Pub. Health Rep., 1919, *34*, 427.
Winslow, C.-E. A., Greenburg, L., and Greenberg, D.: The Dust Hazard in the Abrasive Industry. U. S. Pub. Health Rep., 1919, *34*, 1171.
Winslow, C.-E. A., Greenburg, L., and Reeves, E. H.: The Efficiency of Certain Devices Used for the Protection of Sand Blasters against the Dust Hazard. U. S. Pub. Health Rep., 1920, *35*, 518.
Winslow, C.-E. A., and Greenburg, L.: Industrial Tuberculosis and the Control of the Factory Dust Problem. THIS JOUR., 1920-1921, *2*, 333, 378.
Iszard, M. S.: Estimation of Toxic Water Soluble Dust with the Palmer Apparatus. THIS JOUR., 1920-1921, *2*, 344.
71. Report of the Committee on Standard Methods for the Examination of Air. Am. Jour. Pub. Hyg., 1910, *20*, 346; Am. Jour. Pub. Health, 1913, *3*, 78; 1915, *5*, 250; 1917, *7*, 54.
72. Report (Fourth Supplementary) of the Committee on Standard Methods for the Examination of the Air. Am. Jour. Pub. Health, 1920, *10*, 450.
73. Smyth, H. F., and Iszard, M. S.: The Practical Hygienic Efficiency of the Palmer Apparatus for Determining Dust in Air. THIS JOUR., 1921-1922, *3*, 159.
74. Trostel, L. J.: Efficiency of the Palmer Apparatus for Explosive Carbonaceous Dusts. Jour. Am. Soc. Heating and Ventilating Eng., 1922, *28*, 853.
75. Greenburg, L., and Smith, G. W.: A New Instrument for Sampling Aerial Dust. U. S. Bur. Mines, 1922, Rep. Investigations 2392.
76. Lamb, A. B., Wendt, G. L., and Wilson, R. E.: A Portable Electric Filter for Smokes and Bacteria. Tr. Am. Electrochem. Soc., 1919, *35*, 357.
77. Engler, C., and Wild, W.: Mittheilungen über Ozon. Ber. d. deutsch. chem. Gesellsch., 1896, *29*, 1933.
78. Ehrenberg, P., and Schultze, K.: Die "Unbenetzbarkeit" von Böden und feinen Pulver überhaupt. Kolloid Ztschr., 1914, *15*, 183.
79. Rudge, W. A. D.: A Note on the Electrification of the Atmosphere and Surface of the Earth. Phil. Mag., 1912, *23*, 852. On the Electrification Associated with Dust Clouds, *Ibid.*, 1913, *25*, 481.
80. Lamoreaux, W. F.: The Feld Scrubber for

Cleaning Metallurgical Smoke. Engin. and Min. Jour., 1922, *113*, 198.
81. Bush, H. J.: Electrical Precipitation. Jour. Soc. Chem. Indust., 1922, *41*, 22T.
82. Briggs, L. J.: On the Adsorption of Water Vapor and of Certain Salts in Aqueous Solution by Quartz. Jour. Phys. Chem., 1905, *9*, 617.
83. Hill, E. V., and Armspach, O. W.: Further Studies in Methods of Dust Determination. Jour. Am. Soc. Heating and Ventilating Eng., 1919, *25*, 391.
84. Aitken, J.: On the Formation of Small Clear Spaces in Dusty Air. Tr. Roy. Soc. Edin., 1884, *32*, 239.
85. Bancroft, W. D.: Thermal Filters. Jour. Phys. Chem., 1920, *24*, 421.

BOOK REVIEWS

THE TWELVE-HOUR SHIFT IN INDUSTRY. By The Committee on Work-Periods in Continuous-Industry of the Federated American Engineering Societies. Cloth. Pp. 302 with introduction and index. New York: E. P. Dutton & Company, 1922.

This book contains an interesting and careful survey of the twelve-hour shift as it exists in American industry, together with a more detailed discussion of the problem as it applies to the iron and steel industry in particular. To the reader interested in problems of public health, however, the most striking thing about the book is the entire absence of consideration of the possible effect of the twelve-hour shift upon the health of workers.—*K. R. Drinker.*

INTERNATIONAL REVIEW OF INDUSTRIAL DISEASES. By Dr. *Ludwig Teleky* and Prof. Dr. *Ernst Brezina*. Paper. Pp. 118 with index. Berlin: Julius Springer, 1922.

The report for the year 1919 by Teleky and Brezina covers the Factory Inspection Reports of Germany, Austria, Switzerland, England, and Holland.

Lead Poisoning.—Among painters in Germany lead poisoning has appreciably diminished because of the scarcity and high price of white lead. Ten cases of lead poisoning were reported in Prussia, two from smelting, three from the plate moulding room of a storage battery plant, and five from a tile works. These last were women who scraped the excess glaze from the edges of the tiles. It is interesting to note that, since milk can no longer be furnished to lead workers, in some places, such as a lead oxide plant, they are advised to chew tobacco in order to encourage the flow of saliva and thus be able to get rid of the inspired dust; while the report of the Dutch inspectors states that new employees are warned of the danger of chewing tobacco. Only eight cases of lead poisoning were reported in the whole year in Saxony because of the lessened use of lead, and the same thing seems to be true of other parts of Germany.

In England lead poisoning increased in 1919, as compared with 1918, with the resumption of industry. The trade that stands at the head now is no longer the production of white lead or the potteries or the painting of vehicles, but the manufacture of storage batteries. The suggestion is made that mechanical plate pasting be substituted for hand work. On the ground of an examination of 25,000 notified cases of plumbism the British report emphasizes the overweening importance of fumes and dust in their causation. It calls attention to the high mortality especially among the pottery cases, 28.1 per cent., usually from chronic nephritis or apoplexy after many years' exposure.

Among the occupations which should be forbidden to women and to lads under 18 years are the following, according to the decision of the International Labour Bureau: production and use of solder with more than 10 per cent. lead; melting lead or zinc scrap on a large scale; mixing and pasting in making or repairing storage batteries; cleaning rooms in which lead smelting and refining, zinc smelting, or preparation of lead oxides, lead colors and lead enamels and glazes, is carried on.

Mercury.—Mercurial poisoning in Bavaria

has occurred in the production of acetic acid from acetylene by the use of large quantities of mercury or oxide of mercury as catalyzer. Another source is the very common substitution of mercury for tin in solder. The cases of mercurialism in Austria have occurred in a factory making incandescent lamps with the use of the mercury pump, and in several fur cutting establishments. Seven cases in England came from the manufacture of scientific instruments, and the making of fulminate of mercury.

Arsenic.—A new use for arsenic and a new danger to workers is the proposed method of destroying parasites in the forests of Potsdam. Compounds containing arsenic acid are heated to 2000° C. and the vapors released. The iron container is half buried in the ground, the cover taken off, a fuse lighted, and the worker departs. The vapors spread for about 20 to 30 meters. Three men who were carrying back a closed container were poisoned by the fumes because the cover came off and for some reason the reaction started up again before they could close it securely. One of the men died after six days' illness.

Of the four cases of arsenic poisoning in England, three were caused by hydrogen arsenide evolved in the course of reduction processes. In dyeing with indigo, zinc and acid were used, one or the other apparently arseniferous for the fumes poisoned two workmen.

Phosphorus.—Twenty years' experience in the manufacture of lucifer matches with phosphorus sesquisulphide has led the Swiss government to consider abandoning the medical control of such factories, and the industrial physicians are in entire agreement with this proposal. On the other hand, a case of phosphorus necrosis is reported from England—a rather unusual case since it developed after only four years' exposure. The man worked in the room where phosphorus sesquisulphide was dried, and was never exposed to fumes except when there was an accidental ignition of the matches.

Hydrogen Sulphide.—Several reports of hydrogen sulphide poisoning come from the German factory inspectors. In Leipzig four workmen were killed by this gas in the course of cleaning the drain pipes of a fur dressing plant. Three of the men were killed in trying to rescue the first who had fainted. The gas had been formed by decomposition, putrefaction, and the interaction of the sulphuric acid and the iron sulphide which the water in the drain pipes contained. It was noted in this case that the gas did not betray itself by its characteristic odor. In Baden three workmen were overcome by hydrogen sulphide fumes, one of them dying, the other two recovering rapidly as soon as they were removed from the poisoned atmosphere. This accident took place in a tannery. The men were filling a vat with "kalzin," said to be a sulphur derivative of calcium. By mistake they added lactic acid instead of more kalzin, and the contact of the acid liberated hydrogen sulphide.

Chlorine, Hydrochloric Acid, Nitric Acid, Etc.—Poisoning with fumes of chlorine is reported from Bavaria. Six carpenters were at work in a factory, apparently making alterations which resulted in the escape of chlorine gas; because of their lack of acquaintance with the danger they did not escape quickly enough and in consequence suffered severe respiratory disturbances but without fatal result. A much more unusual case was that of a man who was in charge of an apparatus in which chlorine was generated and who for a few minutes breathed some of the escaping gas. He was not immediately affected by it for he did not leave his post, and it was not until two days later that he declared himself ill and then, five days later, he died. Another man died of the irritating effects of hydrochloric acid fumes which he had inhaled three days before. One factory reported thirteen cases of chlorine bronchitis, and four very severe cases of illness from breathing chlorine, one of these ending in death. A girl technician died after inhaling sulphuryl chloride gas. A typical case of nitrogen oxide fume poisoning occurred in a brewery in Holland in a man who was cleaning a yeast tank with nitric acid. By 2 o'clock of the following morning he was very ill, the lungs full of moist râles, and he died in the evening in deep coma.

Carbon Monoxide and Carbon Dioxide.—Many cases of carbon monoxide poisoning from leaking gas pipes are reported from Germany from a great variety of factories and workshops. A warning is issued as to the danger of heating closed workrooms with

stoves that have no pipes for carrying off the gases. Even open coke stoves are apparently used in some otherwise excellent shops. Several of the cases of gas poisoning have occurred in the course of drying vegetables. In England the statement is made that carbon monoxide was the cause of more industrial accidents than any other substance. The thirty-three cases of poisoning with blast furnace gas, which contains 25 per cent. carbon monoxide, occurred chiefly among men repairing or cleaning flues and pipes. An unusual case of carbon dioxide poisoning is reported from a brewery. The man was alone in the plant, as it was Sunday, and he climbed into a vat to clean it and was found dead there the next day.

A very singular case of poisoning supposedly from carbon dioxide is reported from Holland from a linseed oil works. The man was sent to clean an oil reservoir which had held for fourteen days a layer of watery residue left behind after the oil had been drawn off. He was let down into the reservoir by a rope around his waist, untied the rope, and then collapsed and fell headlong into the watery residue. A second man was lowered but before he could make any attempt at rescue he lost consciousness, was drawn out and came to himself promptly; by the time the first man was lifted out he was already dead. It was supposed that a yeasty fermentation had taken place in the refuse and had formed carbon dioxide which lay in a thick layer just over the surface of the oily water. An old workman remembered that a similar accident had caused the death of two men many years before. A second oil works, also in Holland, reported a similar accidental death in a man who was let down into a reservoir for crude oil. Water had been let into the reservoir along with the oil, and the workman, who also had untied the rope around his waist, lost consciousness and fell into the fluid.

Poisons of the Fatty Series.—Two girls were poisoned with a so-called turpentine substitute which they used as a solvent. The symptoms included attacks of fainting. The solvent proved to be impure carbon tetrachloride to which some turpentine had been added. The enforced use of substitutes in German industry has led to several cases of poisoning. For instance, a solvent for resins made of acetone, pyridine, methyl alcohol, and mustard oil, caused severe inflammation of the eyes. A woman who was employed in a dry cleaning establishment and who leaned far into a cleaning machine for furs which had carbon tetrachloride as cleansing material died from the effects of the fumes. Trichlorethylene, used as a substitute for benzine in making rubber cement, caused loss of consciousness in two workmen. In another dry cleaning establishment trichlorethylene is used, and its effect is found to be similar to that of chloroform but not so powerful.

These chlorine derivatives of the fatty series are being tested in the Hygienic Institute of Würzburg, and trichlorethylene has shown itself to be comparatively harmless to animals, less poisonous than carbon tetrachloride, and only one-fourth as poisonous as chloroform. Instances of troublesome symptoms from this compound do occur, however. Thus, one woman showed symptoms of chronic poisoning, continual headache, mental dullness, and later insomnia and excitability so that she was obliged to give up work. Two others in the same room complained of more discomfort from the use of trichlorethylene than they had felt when using benzine. Other experts report the same. It is not improbable that trichlorethylene if used continually may have an effect on human beings which is different from that observed in animal experiments. This must be borne in mind in considering the employment of a compound which otherwise, because of its non-inflammable nature, would be highly recommended as a substitute for benzine. Another report comes from a factory making rubber clothing which had substituted trichlorethylene for the usual benzine and benzol in the cement. The women using it complained of illness which they had not experienced under the use of the former solvents.

The substitution of benzol and chlorine derivatives of the fatty series for benzine led to several cases of illness in dry cleaning establishments in Baden. The benzol used is a distillate passing over at about 150° C., and with it is used a solvent consisting of acetone, acetic acid, methyl ether, and methyl alcohol, the latter, however, in only a small proportion.

In a Prussian factory a substitute for alcohol for use in polishing furniture affected the men unpleasantly, giving them headache and dry cough. It proved to contain propyl alcohol, amyl alcohol, and amyl acetate.

Crude acetone caused inflammation of the eyes in a Swiss shoe factory and in a Dutch airplane works where the doping fluid consisted of crude acetone with a little alcohol.

Benzine, Petroleum, Etc.—An increase in the cases of dermatitis among workers in oil distilling is referred by the factory inspectors to the lack of soap. There has also been a great increase of cases of dermatitis from the use of cutting and lubricating oils, and the same is true in briquette factories. More unusual was the eczema of two workmen engaged in dipping cardboard into boiling paraffin, the kettle not being provided with an exhaust pipe for fumes.

In Holland the fumes of hot tar caused complaint of a sense of confusion, dazed feeling, and disorders of taste among the workmen, and in another factory where electric wires were covered with a lacquer made with crude petroleum and so-called turpentine was used, a man and two girls were affected by the fumes. The turpentine proved to be the lighter petroleum distillate with some light coal-tar oils and sulphur compounds. The girls complained of papillomas on their forearms.

Benzol and Benzol Derivatives.—A German factory making oiled silk clothing used benzol as a solvent, and the workmen complained of confusion and dizziness, symptoms which have often been described by painters working in ship cabins with benzol-containing paint. Paint containing pyridine was responsible for loss of appetite, nausea, dizziness, and irritation of the throat. A fatal case of benzol poisoning occurred in a workman who attempted to clean a benzol tank. Another death from benzol had a very unusual history: The workman repaired a pipe from which benzol was leaking. Sixteen days later he was seized with vomiting and severe abdominal pain. An operation showed a slight twisting of the lower small intestine but four days later the man died of cardiac failure. The physicians held that the spasmodic coughing combined with vomiting, which had been caused by breathing the benzol fumes, had given rise to the twisting of the intestine.

Another death from benzol is reported from a plant extracting fat from bones (Germany). The extractor was full of benzol and the fume pipe had become clogged. The workman covered the manhole of the extractor with some old sacks through which the fumes of the heated benzol made their way. He sat down near it to eat his lunch, was found unconscious when the other workmen returned at the end of the noon-day pause, and although oxygen was administered he could not be saved.

In a German oil works two men were ordered to clean an empty tank which had contained rape seed oil, benzol having served as the extraction fluid for the oil. This tank had not been blown out and the first man who entered it fainted and died before he could be lifted out. In the residue at the bottom of the tank a small quantity of benzol was demonstrated.

An English workman died from the effects of toluol fumes which he inhaled in a tank that had contained an ammoniacal fluid and toluol. Usually a Siebe-Gormans gas mask with fresh air supply was used for such work, but this time it had been omitted. The following regulations were formulated by the factory inspectors to govern work of this sort: (1) The period of airing the tank must last six days. (2) The tank must be filled with water and then steam introduced till the water boils. The steam pipe must reach to the bottom of the tank and, either by stirring or in some way, the sludge must be mixed with the water. (3) If a tank has remained empty for some time it must be filled with water and emptied before anyone goes in. (4) Entering a tank and working inside must be permitted only to a man wearing a helmet or mask which is connected by a rubber pipe to fresh air, or provided with a breathing apparatus which will allow him to breathe normal air or a mixture of oxygen and air. (5) Every man who enters a tank must wear a safety belt with a rope attached, and the other end of the rope must be held by a man outside. (6) An oxygen tank with face mask and proper connections must always be available.

In England it has been found that men

over 35 years old who have been employed for ten years and more in handling tar, pitch, and paraffin, are likely to develop obstinate ulcers of the skin which do not heal but which spread and penetrate and can no longer be described as ulcers, but must be included under the term epithelioma, or cancer of the skin. Such lesions must be notified to the Home Office. The scrotum is frequently the seat of such skin cancers. Early operative treatment is the only proper way to handle the cancers. In addition to these serious lesions are milder ones, acne, the formation of comedones and pustules on the face, neck, and forearms. Later reddened spots appear, warts, but without ulcer formation. These do not come under the notification requirement.

Statistics from five Dutch briquette factories show the incidence of skin lesions among such workers. The lesions found were inflammation of sweat and sebaceous glands, flat and raised efflorescences, warts, and furuncles. Three hundred and ninety-five men were examined, of whom 138 had been employed less than one year. Lesions on the exposed skin were found in ninety-six, on the covered skin in seventeen, and in both places in nine. Seven suffered from inflammation of the eyes.

The painters in a German factory making agricultural machinery suffered with dermatitis which covered hands, arms, and face, and also with swelling of the eyelids and burning of the eyes, leading in some cases to fairly prolonged incapacity. The cause was found to be various coal-tar distillates used as substitutes for turpentine and varnish.

Frequent cases of dermatitis are reported from a German phenylhydrazine plant among the men who wrap the product in cloths for the filter. An explosion of a distilling kettle full of this compound resulted in the death some days later of one workman and inflammation of the eyes of a large number of others.

Six workmen in German coal-tar dye plants are reported as having cancer of the bladder, one working in diamine colors, one in aniline blue, one in eosin and rhodamine, one in basic colors, one in chrome colors, and one in alizarin. There was also a case of papilloma in a man who used to produce fuchsin but who has been pensioned for many years. Skin diseases are reported in anthracene purification, caused by ethylene chloride and tetrachlorethylene.

In a German rubber goods factory men at the mixing mills complained of feeling ill and of slight stomach disturbance. It was suspected that the use of aniline oil as an accelerator was responsible for this since the odor of aniline could be detected in the mill room.

Milk is furnished to all of the workmen in a coal-tar dye works who come in contact with nitro and amido bodies.

A report from Dresden discusses the effect of tobacco dust upon the workers. There is a very general irritation of the throat and mouth which is purely mechanical and shows itself in a feeling of thirst and inclination to cough, but many become accustomed to the irritant and later suffer no discomfort. The nicotine does not seem to exert any effect.

Great precautions are taken in Germany in connection with the use of hydrocyanic acid for the destruction of vermin and plant parasites. The procedure is entrusted only to certain firms. The police warn all houses in the vicinity of the building to be disinfected, and the streets are shut off. The gas is produced by the action of sulphuric acid on sodium cyanide, and the men who prepare it and who later enter the gas-filled rooms wear army gas masks.

A diminution in the number of cases of anthrax in Germany is reported during the war and attributed to the blockade which prevented the entrance of foreign skins, while in England, the cases increased because of the increased use of such skins. The British report shows that between 1908 and 1919, 11,077 hides were examined and 781, or 7.2 per cent., found to contain anthrax bacilli. The highest percentage was in goat's and camel's hair, the next highest in Egyptian wool, and the next in East Indian wool. The British committee concludes that disinfection by steam is not practicable and that formaldehyde is the only disinfecting compound that has proved itself effective. The greatest difficulty is encountered in breaking up the clots of blood so that the killing of the anthrax spores is possible.—*Alice Hamilton.*

ANNOUNCEMENT OF

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The Eighth Annual Meeting of the American Association of Industrial Physicians and Surgeons will take place in Buffalo, October 1, 2 and 3 of this year. It will be held in the New Statler Hotel during the same week as the annual meeting of the National Safety Council, and one or more sessions will be in conjunction with the Health Service Section of that organization.

An excellent program is being prepared by the program committee, of which Dr. C. D. Selby of Toledo is chairman.

It is hoped and anticipated that a large number of members will be present at Buffalo. It is fairly central and new territory so far as the annual meeting of our Association is concerned.

Will members of the Association who wish to read papers at this meeting please communicate as soon as possible with Dr. Selby, 655 Spitzer Bldg., Toledo, Ohio.

J. I. H.
May, 1923